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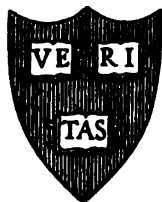
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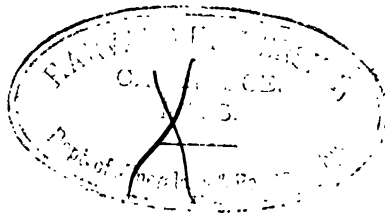
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MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY.

Publication 15.
Geological Series 12.

THE BRINE AND SALT DEPOSITS OF MICHIGAN

THEIR ORIGIN, DISTRIBUTION AND EXPLOITATION

BY

CHARLES W. COOK.

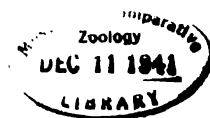


A thesis submitted in partial fulfillment of
the requirements for the degree of Doctor
of Philosophy in the University of Michigan

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE BOARD OF
GEOLOGICAL AND BIOLOGICAL SURVEY FOR 1913

1914
WYCKOFF HALLENBECK CRAWFORD CO., STATE PRINTERS
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SURVEY

1914.

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LETTER OF TRANSMITTAL.

To the Honorable the Board of Geological and Biological Survey of the State of Michigan:

Governor Woodbridge N. Ferris, President.

Hon. Wm. J. McKone, Vice President.

Hon. Fred L. Keeler, Secretary.

Gentlemen:—I have the honor of transmitting to you herewith manuscript of a report on the Brine and Salt Deposits of Michigan, by Dr. Charles W. Cook, with the recommendation that it be printed and bound as Publication 15, Geological Series 12. In thoroughness of treatment and excellence of presentation this monograph does full credit to the importance of the salt industry of the state. The quantity and value of the annual salt production of Michigan is greater than that of any other state and the quantity of natural brines and rock salt in the Southern Peninsula is of such enormous magnitude that it may be said, without exaggeration, that Michigan sources of available salt are inexhaustible.

The investigation and studies on which this report is based have been in progress since early in 1910. It was expected in the beginning that earlier publication would be possible but full compensation for the delay is afforded in the resulting more comprehensive study and treatment of the subject of investigation.

Very respectfully yours,

R. C. ALLEN,

Director.

Lansing, Michigan, Jan. 19, 1914.

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INTRODUCTION.

For nearly half a century, Michigan has been one of the leading salt producers of the United States, and while a number of reports, both by the geological survey of the state and by private individuals, have described the industry in its various phases, they are, for the most part, antiquated and many of them are no longer available. The present report aims not only to bring together the important facts contained in the previous papers but also to make such additions as are warranted by the more recent developments and the present state of our knowledge. Furthermore, it is hoped that some light may be shed upon the possible origin of the salt brines and rock salt from which the article of commerce is obtained.

The subject matter has been treated under the following general headings: Historical Account, Origin of the Salt Deposits, Geology of the Saliferous Rocks, Methods of Manufacture, The Product, and Salt Producing Areas. An appendix giving the bibliography on the subject has also been added.

FIELD WORK.

The major portion of the field work was performed by the author during the summer of 1910, covering a period from June 27 to September 21. During this time, not only the present salt producing areas but also the districts which have been producers in the past were visited. Information was sought concerning the geological occurrence of the saliferous rocks, the composition of the brines and their products, the equipment and the methods of manufacture of the various companies, and the production and the economic conditions influencing it, together with the history of the development of the industry. An attempt was also made to locate definitely all salt wells, both the producing and non-producing. It was found, however, that in a number of instances, especially in the older districts, this was not possible. Additional visits to the producing areas were made in June 1911.

ACKNOWLEDGMENTS.

The writer wishes to take this opportunity to record the courteous treatment and generous cooperation afforded by the various companies and their officers in the preparation of this report. For the most part

the information and assistance were gladly and cheerfully given. Thanks are due especially to Messrs. E. G. Filer, R. A. Nickerson, J. J. Hubbell, and Geo. Ray of Manistee; P. Hardy, J. H. Brogan, and Geo. Abair of Ludington; H. H. Dow and E. P. Rice of Midland; Temple Emery and M. L. Davies of Bay City; T. P. Whittier, W. J. Mason, J. P. Warrick, and Geo. B. Willcox of Saginaw; Otto Huette of Port Huron, F. W. Moore of St. Clair, S. C. McLouth of Marine City, and Jos. P. Tracy of Detroit. To Dr. Wm. H. Hobbs, Professor of Geology in the University of Michigan, for many valuable suggestions and criticisms, and to Mr. R. C. Allen, State Geologist, for the facilities afforded by the Michigan Geological Survey, the author is heavily indebted.

DISTRIBUTION OF SALT DEPOSITS.

As in the case of all necessities of life, nature has provided us amply with salt. Its distribution, both areal and geological, is very widespread, so that we find it in nearly every country and in rocks of practically all ages from the earliest Paleozoic to the present time. The occurrence of salt in both the Eastern and Western Hemispheres has been so recently discussed by Harris¹ that it need not be taken up in this connection. The distribution within the United States is shown in the following table, which has been compiled from various reports, and private communications from the several state geologists.

	Brine	Rock Salt
Michigan	Carboniferous (Mississippian)	Silurian (Salina)
New York	Ordovician to Devonian.	Silurian (Salina)
Ohio	Carboniferous (Mississippian)	Silurian (Salina)
Kansas	Cretaceous	Carboniferous
Louisiana		Tertiary
California	Recent*	Tertiary (Eocene)
West Virginia	Carboniferous (Pottsville and Logan Series)	
Texas	Cretaceous	Carboniferous
	Carboniferous	(Permian)
Utah	Recent	Recent
Virginia		Carboniferous

¹Bull. No. 7, Geol. Sur. of La., 1907.

*Ocean water.

	Brine	Rock Salt
		(Greenbrier limestone)
Pennsylvania	Carboniferous (Pocono)	
Nevada		Recent
Oklahoma		Carboniferous (Permian)
New Mexico		Recent
Nebraska	Carboniferous (Dakota Shales)	

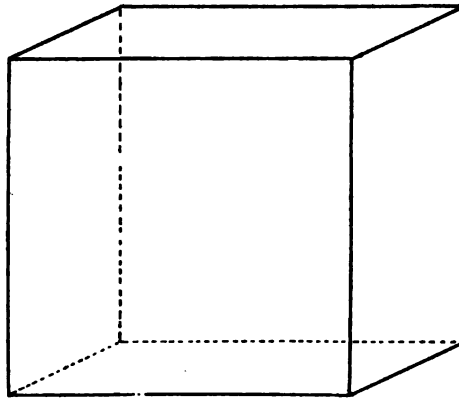


Figure 1. A cube.

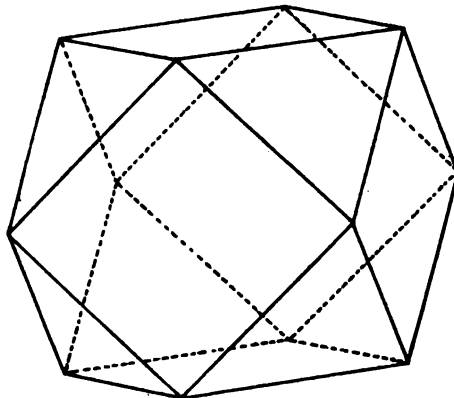


Figure 2. Combination of a cube and octahedron, the cube predominating.

INTRODUCTION.

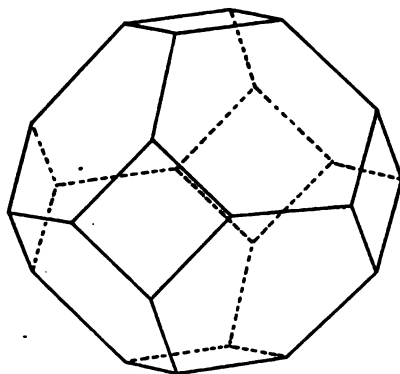


Figure 3. Combination of a cube and octahedron, the octahedron predominating.

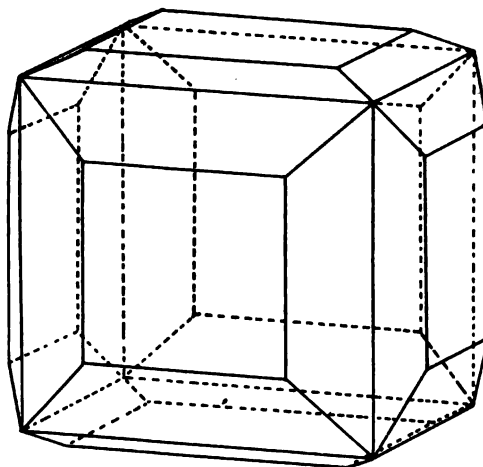


Figure 4. Combination of a cube and tetrahedron.

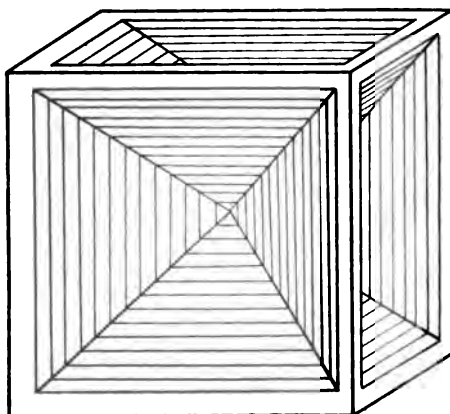


Figure 5. Showing hopper-shaped crystal of halite.

PHYSICAL PROPERTIES OF SALT.

Common salt is composed of sodium and chlorine united in the proportions represented by the formula NaCl , or 39.59 % sodium and 60.41 % chlorine. It occurs in solution in sea water and in brines and in the solid state as rock salt or the mineral halite. Halite crystallizes in the cubic system, the predominating form being the cube. Among other forms which have been noted are the octahedron, rhombic dodecahedron and tetrahexahedron. Figs. 1-4 show different types of development. The crystals also often show a skeletal or hopper-shaped form as illustrated in Fig. 5. One of the most characteristic properties of halite is its perfect cubical cleavage. That is, when struck a sudden blow, it tends to break along planes parallel to the faces of a cube. It has a hardness according to Mohs scale of 2.5, and a specific gravity of 2.1-2.6¹; pure crystals, 2.135. The color when pure is white, but it may be yellow, brown, red, purple, blue, green, or black, due to the presence of impurities. It is transparent to translucent, and is usually found interstratified with anhydrite, gypsum, shale and limestone. It may also have, as its associates, various combinations of alkali and alkaline earth chlorides and sulphates.

PREVIOUS WORK.

As already stated in the opening paragraph, a number of reports have appeared from time to time dealing with the different aspects of the salt industry of Michigan. The important points brought out in these papers arranged in chronological order are given below:

1838. Dr. Houghton² reported that the brine springs of Michigan might be divided into five groups as follows: On the Grand river near Grand Rapids, on the Maple river in Gratiot county, on the Tittabawassee river in Midland county, in Macomb county and on the Saline river in Washtenaw county. No important indications of salt springs were found south of a line between Monroe and Grand Rapids. He advanced the idea that the geology of Michigan was similar to that of the Ohio Valley, but believed that the brines of Michigan occurred in a lower formation than those of Ohio.

1861. Alexander Winchell³ outlined a correct conception of the geology of Michigan and thus furnished the first basis for the scientific search for saltbearing rocks. The following practical suggestions⁴ for the successful discovery of brines were laid down by him at that time:

- "1. The occurrence of a salt spring is a fact of no consequence whatever, except in connection with all the other geological facts.
2. Brine is found issuing at the outcrops of the coal measures,

¹Dana's System of Mineralogy, 6th Edition, 1904, p. 154.

²First Annual Report of the State Geologist, Joint Doc. 1838.

³Geol. Sur. Mich. 1st Bien. Rpt., 1860, pp. 165-193.

⁴Ibid. pp. 165-6.

the Gypseous Group, the Napoleon Group, the Marshall Group and the Onondaga Salt Group. In Ohio, it also issues from the Coal Conglomerate, the Hamilton Group and the Hudson River Group.

3. Only two of these groups will be found, in our state, to produce brine of sufficient strength for manufacturing purposes; and at present only the Gypsum Group is known to do this.

4. Before deciding on the indications of a salt spring, therefore, it is necessary to know from what geological formation it issues. Here the elaborate investigation of the order of distribution of our strata, finds one of its applications.

5. Before the origin of a brine can be known, we must ascertain whether it flows out horizontally at an outcrop, or rises vertically through a fissure in the strata overlying the salt rock. A fundamental mistake, committed in the early explorations for salt, grew out of the assumption that the brine of our springs generally rises through fissures, and may be sought by boring in the vicinity of the springs.

6. Most of our springs issue at *outcrops* of saliferous strata; so that the moment we begin to bore in such situations, we find ourselves *beneath* the source of the salt.

7. The source of the salt must be sought by traveling from the spring toward the center of the basin, when, by boring down, the brine may be expected in increased strength and quantity.

8. Our saliferous basin extends from Grand Rapids to Sanilac County, and an unknown distance toward the north. Within the basin, the area covered by the Coal Measures may be taken as the area underlain by strata of maximum production.''

Winchell further announced the occurrence of the Onondaga Salt Group (Salina) in Michigan from outcrops, especially on islands near Mackinac and in the southern part of Ida township in Monroe County, which he correlated with the Onondaga Salt Group of New York.

1862. Winchell reviewed the progress of the industry, and called attention to the fact that the erroneous views of Dr. Houghton upon the geological structure of the southern peninsula had been responsible for the early failures. He recognized three salt horizons, the Coal Measures with the Parma Sandstone below as the reservoir, the Michigan Salt Group or Gypsum Group with the Napoleon Sandstone as a reservoir, and the Onondaga Salt Group. The latter he believed to occur 750 feet⁶ below the Michigan Salt Group.

1867. Dr. H. C. Hahn, who was general manager of the salt works of the New York and Saginaw Salt Company at Zilwaukee, published a paper⁷ upon the manufacture of salt in the Saginaw Valley. He made

⁶"On the Saliferous Rocks and Salt Springs of Michigan." Am. Jour. Sc. Vol. 34, 2nd Ser. pp. 307-11.

⁷Berg und Huettenmännische Zeitung, Vol. 26, 1867, pp. 97-9, 135-7, 161-3, 185-7, 209-11, 221-3, 237-9, 254-7, 283-4, 305-7, 337-339.

a large number of analyses of the brines, bitterns and salt of the various companies, from which he worked out formulas for determining their composition under different conditions, and made suggestions as to the best methods of manufacture in order to insure the best grade salt and the greatest economies in manufacture. He, however, dealt only with the manufacture of kettle and solar salt. Hahn recognized two salt groups, the Michigan and the Onondaga. The former included both the Coal Measures and Gypsum Group of Winchell, and the latter he states to occur at Pt. Austin at a depth of 339 meters, and at Detroit below the Helderberg. His conception of the geology of the southern peninsula of Michigan was therefore somewhat different from that of the present time.

1876. Dr. C. Rominger⁸ pointed out that Winchell's correlation of the beds at Ida with those of the Onondaga of New York is not justified by facts.

1876. S. S. Garrigues⁹, State Salt Inspector, gave a general review of the salt industry of Michigan, including methods of manufacture, composition of the brines and inspection of the product.

1876. S. B. McCracken¹⁰ gave a brief historical review of the industry.

1881. S. S. Garrigues¹¹ prepared under the direction of the legislature of the State a statistical report on the salt industry of Michigan.

1881. Dr. Hahn¹² published an article on the manufacture of solar salt.

1888. Thos. M. Chatard¹³ presented a report on the chemistry of brines and discussed the methods and costs of manufacture in the Michigan, New York and Kanawaha, W. Va., districts with suggestions as to improvements in manufacturing methods.

1895. Dr. L. L. Hubbard¹⁴ discussed the various theories for the origin of salt deposits, placing special emphasis on the theory of Ohsenius, which he appears to think directly applicable to the Michigan salt deposits, as may be seen from the following quotation:

"To account for the deposit of the salt of Michigan, in all four of the salt horizons, the assumption of an uninterrupted connection of this basin with the sea, for a long period of time, does not seem, so far as the evidence goes, to be required."

1895. Dr. A. C. Lane¹⁵ goes a step further when he says:

"The period of the Monroe beds is that of the Salina and Lower

⁸Geol. Sur. Mich. Vol. III, 1876, p. 35.

⁹Ibid, Appendix B.

¹⁰"The State of Michigan embracing Sketches of its History, Position, Resources, and Industries," Lansing, 1876, pp. 69-72.

¹¹Statistics Relating to the Salt Industry of Michigan. Lansing, 1881.

¹²Berg und Huettenmännische Zeitung, 1881, pp. 369-372, 389-391.

¹³U. S. Geol. Sur., Seventh Ann. Rpt., 1886-7, pp. 497-527.

¹⁴Geol. Sur. Mich., Vol. V, Part II, 1881-1893, pp. ix-xix.

¹⁵Geol. Sur. Mich., Vol. V, Part II, 1881-1893, p. 27.

Helderberg. At that time, Michigan was covered by an excessively salt sea which stretched from Wisconsin to New York, was bounded by a continent on the north and east, on the west by low land in Wisconsin (the edge of the Helderberg is found barely extending to just north of Milwaukee), and on the south by a great bar, or reef, or flat in Ohio, which seems to have been just awash..... If we imagine tides like those of the Bay of Fundy rushing over this flat, producing this breccia and conglomerate and bringing fresh supplies of water to the enclosed sea, and furthermore that the sea was exposed to a hot sun and received but little accession of fresh water from rivers—this latter is shown to be true by the scarcity of mud and sand—we have the conditions of the Helderberg or Monroe deposits, conditions which are evidently favorable to the formation of a sea charged with salts.”

Dr. Lane also¹⁶ discussed the composition of the various mineral waters and brines.

1898. J. J. Hubbell¹⁷ in a paper entitled “A Barrel of Salt” gave a description of a modern salt block and its operation. A more detailed reference to this article will be made in the chapter on the manufacture of salt.

1900. Dr. A. C. Lane¹⁸ in his report on Huron County, discussed the composition of the Huron County brines and the salt industry in that district.

1900. S. S. Higgins¹⁹ gave a brief historical review of the industry.

1901. Dr. Lane²⁰ compared the brine of the Berea Grit at Kilmaster, Alcona County, with the brine from the same horizon in the wells at White Rock and Pt. Austin in Huron County. The Dundee brines there are too high in sulphides and salts other than sodium chloride to be satisfactory in the manufacture of salt.

1901. The same author²¹ gave a brief report on the developments in the salt industry, treating especially the wells along the Detroit and St. Clair rivers.

1906. W. F. Cooper²² reported on the salt industry in Bay County. He discussed the various brine horizons and the composition of the brines.

1907. Eugene F. Bradt²³ described the method of overcoming the exceedingly large flow of underground water encountered in sinking the shaft of the Detroit Salt Co.

1907. Geo. B. Willcox²⁴ presented the results of experiments in

¹⁶Loc. cit. pp. 32-34.

¹⁷Michigan Engineer's Annual, 1898, pp. 31-44.

¹⁸Geol. Sur. Mich. Vol. VII, Part II, 1896-1900, pp. 135-36, 224-5.

¹⁹“The Salt Industry in Michigan,” Mich. Pol. Sc. Assoc. Vol. 4, No. 2, p. 190.

²⁰Geol. Sur. Mich., Ann. Rpt. for 1901, pp. 75-6.

²¹Ibid, pp. 241-2.

²²Geol. Sur. Mich., Ann. Rpt. for 1905, p. 389; 1906.

²³“Crevices in a Salt Shaft,” Mich. Eng., 1907, pp. 17-25.

²⁴“Evaporation Tests of a Salt Grainer,” Mich. Eng., 1907, pp. 164-189.

grainer evaporation, showing the steam consumption per barrel of salt manufactured under ordinary conditions of operation.

1908. Willcox²⁵ gave a detailed description of a modern grainer block, showing the more recent developments in mechanical methods and appliances from the standpoint of a mechanical engineer.

1909. Dr. Lane²⁶ gives a general summary on the geological section of Michigan with a possible explanation²⁷ for the occurrence of the salt deposits of the Salina directly on top of dolomite with anhydrite above the salt. He also, apparently, would apply the Ochsenius theory to the formation of the salt deposits. The following quotation will perhaps serve to make his position clear:

"But in some it appears as if the salt really did lie directly upon the dolomite. I have thought of this possible explanation. The thickness of salt deposited shows that the basin must have been fed from without. Suppose that it was not only fed by straits from the ocean, but partially or wholly by alkali waters draining from surrounding lands. We know pretty well that in sea water of that day, calcium chloride and magnesium chloride were present beside sodium chloride, as they are to-day, but calcium chloride was relatively much more important. Suppose to a more or less concentrated calcium chloride solution water containing sodium carbonate or sulphate like the alkali water of the western plains were added. The carbonate would throw down calcium magnesium carbonate very promptly. The sulphate might throw down calcium sulphate, in proper conditions. But calcium chloride is much more soluble than sodium chloride and the replacement of calcium by sodium in the base would tend to make the chlorides less soluble. On the other hand, calcium sulphate is much more soluble in a sodium chloride solution than in a calcium chloride one. Thus the addition of sodium carbonate would tend to retard its deposition. If then there was a good supply of sodium carbonate, the order of precipitation might be first dolomite, then salt, then anhydrite."

1910. Professors A. W. Grabau and W. H. Sherzer²⁸ consider that the deposition of the Salina took place under arid conditions in shallow playa lakes in basin shaped depressions. The salt they believe was derived from the Niagara and other marine limestones on the surface of which it appeared as an efflorescence. It was removed by intermittent desert streams and carried to the ephemeral lakes in which it was later deposited.

1911. Albert H. Fay²⁹ described the construction and equipment

²⁵ "Mechanical Methods and Engineering Feature of Large Salt Plants," Trans. Am. Soc. Mech. Eng., Vol. 3, pp. 1065-1085; 1908.

²⁶ Geol. Sur. Mich. Ann. Rpt. for 1908, pp. 43-105; 1910.

²⁷ Ibid, p. 62.

²⁸ Mich. Geol. and Biol. Sur., Pub. 2, Geol. Ser. 1, pp. 235-237, 1910.

²⁹ "Shaft of the Detroit Salt Co", Eng. and Min. Jour., Vol. 91, No. 11, pp. 565-569; 1911.

of the salt shaft constructed by the Detroit Salt Co., at Oakwood, Wayne County, Michigan.

In addition to the above mentioned papers, statistics have been published annually; by the State Salt Inspector since 1869, by the Commissioner of Mineral Statistics since 1878 and by the United States Geological Survey since 1880.

CHAPTER I.

HISTORICAL ACCOUNT.

The existence of salt springs, in the southern peninsula of Michigan, was known to the Indians before the coming of the white man. It is also reported that, very soon after the arrival of the first settlers, attempts were made, on Salt River in Macomb County and also at Saline in Washtenaw County, to manufacture salt from the waters of these springs. However, the first step in the development of the industry may be said to have been taken by the convention assembled in Detroit, May 11, 1835, for the purpose of formulating a state constitution. From this point, two periods of development may be recognized. The first period, that of governmental development, was very largely one of failure; the second, or period of private initiative, has been marked by success almost from the beginning.

GOVERNMENTAL DEVELOPMENT.

The Constitutional Convention of 1835 submitted to Congress, with the proposed constitution, an ordinance, one of the articles of which reads as follows: "All salt springs within the state, and the lands reserved for the use of the same, at least one section including each spring, shall be granted to the State, to be used or disposed of as the Legislature may direct." As a result of the request, the Act of Congress admitting Michigan into the Union gave to the authorities the right to select seventy-two sections as state salt lands.

At the first meeting of the Legislature, Dr. Houghton was appointed State Geologist. He immediately began an examination of the salt springs of the state and his first annual report was very largely devoted to the discussion of the same. His investigations showed that important saline indications were limited to five districts, namely,—on the Grand river in Kent county, on the Maple river in Gratiot and Clinton counties, on the Tittabawassee river in Midland county, in Macomb county and on the Saline river in Washtenaw county. He pointed out the importance of these springs and urged their early development by the state. Accordingly, by the Act of March 24, 1838, he was directed to commence boring for salt at one or more of the state salt springs, \$3,000 being appropriated to defray the expenses. Before beginning operations, Dr. Houghton visited the salt springs of New

York, Ohio and Virginia, to acquaint himself with the methods there in use. In June, a well was begun in Midland county, on the Tittabawasse river about one half mile below the mouth of Salt Creek. A month later, a second well was started on the Grand river three miles below Grand Rapids.

Although the Legislature of 1839 appropriated \$15,000 to continue operations at the state salt springs, no great progress was made as experienced operators could not be obtained, because they were fearful lest the climate should be unhealthy. Therefore, in 1841, bids for the completion of the work were asked for and the contracts awarded,—the Grand river contract to the Hon. Lucius Lyon, and the Tittabawasse to Mr. Ira T. Farrand. These contracts called for a well three hundred feet deep. The Grand river contract was completed Dec. 23, 1841, a flow of one hundred and thirty gallons per minute being obtained. The strength of the brine, however, was not sufficiently great to warrant an attempt to manufacture salt. The state geologist, therefore, recommended that the well be continued to the second salt rock, which he estimated would be reached at about seven hundred feet. Upon this recommendation, the Legislature of 1842 appropriated \$15,000 to continue the work and by the close of the year a depth of about eight hundred feet had been attained. The rock at that point was found to be of such a close texture that the circulation of the waters was very much impeded and the idea of production was abandoned.

In the meantime work at the Tittabawasse well had progressed very slowly. After four years of intermittent work a depth of only one hundred and thirty-nine feet had been reached, where a boulder, which the drills could not penetrate, was encountered and the work was abandoned.

Following these unsuccessful attempts to develop the state salt lands, an act was passed by the Legislature providing for the surveying and leasing of said lands. The lessee was to pay to the state four cents per bushel of fifty-six pounds of salt for the water used. The act also authorized the governor to plan for the sale of such salt lands as were not needed. In the following years, a series of laws and resolutions providing for the sale of these lands was passed and various sections were appropriated for different state institutions.

The cause of the early failures in the location of salt wells was very largely a misconception of the geology of the southern peninsula of Michigan. It was, therefore, not until the appearance of Professor Winchell's first report, in 1860, that there was any basis for a scientific search for salt brines.

PRIVATE INITIATIVE.

While the work on the state salt wells was at a standstill, the Hon. Lucius Lyon, in 1840, began a well near the Bridge Street bridge in Grand Rapids, which was completed at a depth of six hundred and sixty-one feet in July of the following year. From this well a strong flow of water, about one fifth saturated, was obtained. At this time, salt commanded a price of three dollars per barrel. He was, therefore, able to make a small quantity of salt without loss.

It was not until nearly twenty years later that any further attempts were made to manufacture salt in Michigan. In February, 1859, very largely through the exertions of Dr. Geo. A. Lathrop of East Saginaw and Mr. James Scribner of Grand Rapids, the Legislature passed "An Act to encourage the manufacture of salt in the State of Michigan." By the provisions of this act, all property employed in the manufacture of salt was exempted from taxation, and a bounty of ten cents per bushel was to be paid for all salt obtained by boring in the state. The bounty was to be paid, however, only when at least five thousand bushels should have been manufactured. Under this stimulus, the industry was revived at Grand Rapids and a well was also started at East Saginaw.

At Grand Rapids, six wells were put down and plants erected for the treatment of the brines. A small amount of salt was manufactured, but on account of the weakness of the brine, the project was finally abandoned after an expenditure of twenty-five thousand dollars.

On March 30, 1859, the subscription book of the East Saginaw Salt Manufacturing Co. was opened. The stock of the company having been disposed of, ten acres of land just at the lower part of East Saginaw was purchased from Mr. Jesse Hoyt, conditional upon the finding of brine, and the sinking of a well was begun under the directions of Dr. Lathrop. The striking of the first brine was reported on Feb. 7, 1860. A plant for the treatment of the brine was immediately erected and the boiling of salt was begun in the latter part of June.

Almost immediately, other companies began to sink wells and so rapid was the progress of the industry, that by July 1862 twenty-three companies were in operation or in the process of construction in the Saginaw Valley.

The encouragement of the industry by the state as provided in the Act of Feb. 15, 1859 was to be short lived. In March 1861 the former bounty law was amended so that it was to apply only to companies actually engaged in the manufacture of salt previous to Aug. 1, 1861. Furthermore, the tax exemption was limited to five years from the date of organization, and the bounty was reduced to ten cents per barrel

BRINE AND SALT DEPOSITS OF MICHIGAN.

TABLE I.

Year.	No. of companies.	No. of blocks.				No. of solar covers.	Capacity, barrels.
		Kettle.	Pan.	Steam.			
				Grainier.	Vacuum.		
1860	1						
1861	7						
1862	23						
1863	57	75	6	13		1540	
1864	67	79	7	31		4949	
1865							
1866	61			†113			
1867	60			†111		4207	
1868	62			†111		4304	
1869	69			†116		4354	1,212,500
1870	61	72	15	28		3347	1,247,000
1871	68	74	14	32		3347	1,408,000
1872	50	50	14	34		3847	1,158,000
1873	62	38	17	36		4347	1,258,000
1874	68	41	21	41		4371	1,774,000
1875	74	33	22	49		4371	1,800,000
1876	76	30	22	52		4100	2,155,000
1877	79	20	22	71		3800	2,100,000
1878							
1879							
1880	97	3	31	85		4500	3,150,000
1881	105	2	29	90		4500	3,400,000
1882	111		37	96		4500	3,590,000
1883	116		31	100		4500	3,765,000
1884	117		27	101		4500	3,875,000
1885	122		27	106		4500	4,445,000
1886	136		24	116		4500	5,165,000
1887	125		23	118	1	4500	5,165,000
1888	127		14	113	3	4500	5,265,000
1889	122		4	99	3	4000	4,950,000
1890	97		4	99	3	4000	4,950,000
1891							
1892	109		10	98	4	4000	5,425,000
1893	109		7	98	8	4000	5,425,000
1894	109		7	98	8	4000	5,425,000
1895	110		7	98	8	4000	5,425,000
1896	69		4	58	10	3000	6,500,000
1897	61		3	55	9	1500	7,880,000
1898	57		3	53	10	1500	7,830,000
1899	57		3	50	10	1200	7,610,000
1900	50		3	52	11	1000	7,700,000
1901	65		6	56	11	1000	9,500,000
1902	63		6	56	12	1000	9,160,000
1903	57		6	46	13	1000	10,500,000
1904	50		5	42	12	1200	10,150,000
1905							
1906	35		5	31	10	50	9,495,000
1907	34		4	31	10	1170	9,250,000
1908	35		4	33	11		9,260,000
1909	34		4	31	11		9,250,000
1910	30		3	28	13		9,250,000
1911	27						8,600,000
1912	26						
*1913	24						8,490,000

*Dec. 1, 1912, to Aug. 15th following, when law abolishing office of State Salt Inspector went into effect.

† Includes kettle and pan blocks.

with a maximum limit of \$1,000 to any one company. The law was finally repealed entirely March 22, 1869.

However, the industry had become established on so firm a basis that it has continued to grow until in 1905 its production exceeded that of any other state in the Union, and in 1908 it assumed first place in the value of its product as well as in the quantity produced.

The general development of the industry is shown in Table I, compiled from the reports of the State Salt Inspectors, newspaper clippings and other sources, and in Figs. 6 and 7.

In Fig. 6, are shown the curves representing (a) the number of companies operating salt blocks, (b) the total number of blocks in operation, (c) the number of kettle blocks, (d) the number of open pan blocks, (e) the number of grainer blocks, and (f) the number of vacuum pan blocks. The ordinates represent the years from 1860 to 1910 and the abscissae the units. From this diagram, it will be seen that starting with one company in operation at the beginning of 1860, the increase both in operating companies and blocks in operation was very rapid for the first five years. Then for the next five years, with the exceptions of minor fluctuations, the industry remained practically at a standstill, to be followed by a decrease in the number of firms and a still larger decrease in the number of blocks. The explanation for this is to be seen in the line representing the number of kettle blocks. In 1873, however, this backward movement was arrested by the rapid increase in the number of grainer blocks as well as a slight increase in the number of pan blocks. This increase in grainer blocks continued until the maximum number of companies operating and blocks in operation was reached in 1886 and 7 respectively, although the number of pan blocks had reached a maximum in 1882 and then had begun to disappear, the last of the kettle blocks having disappeared the preceding year. During the years 1887 to 1891, a very large number of companies suspended operations owing to a decided drop in the price received for their product, and with the exception of brief revivals in 1892-1895, and in 1901, the number of plants and companies has decreased until the present status was reached in 1905. This great decrease has been due chiefly to the passing of the lumber industry in the Saginaw Valley, and the consequent abandonment of the salt blocks operated in connection with the saw-mills.

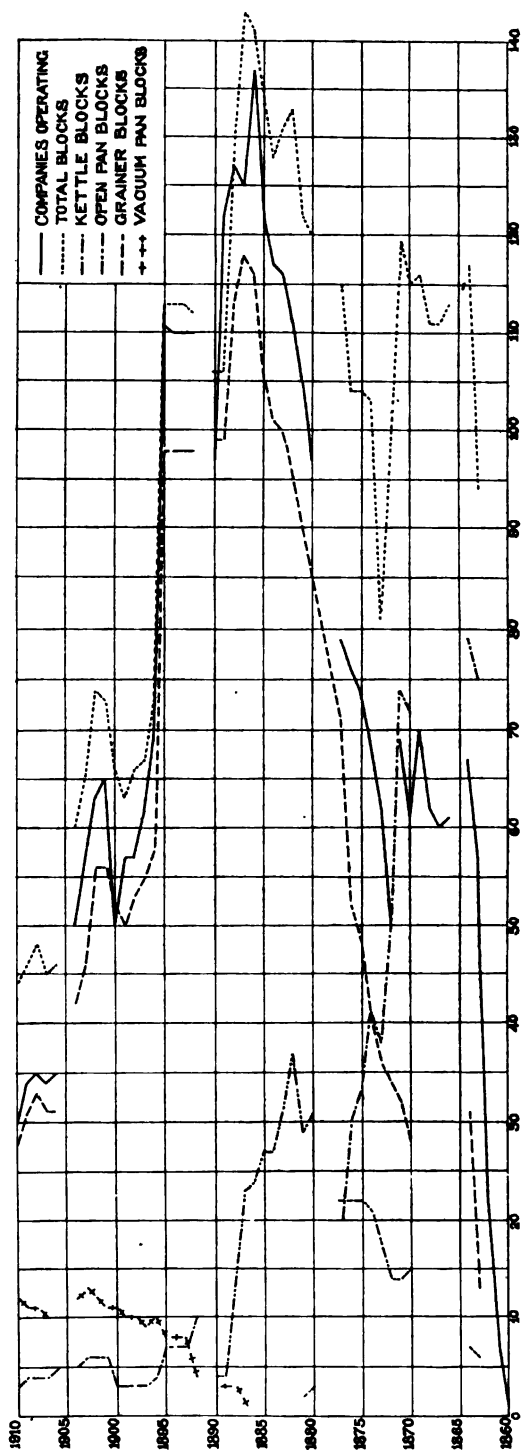


Figure 6. Showing companies in operation from 1860-1910, together with number of salt blocks and the processes employed.

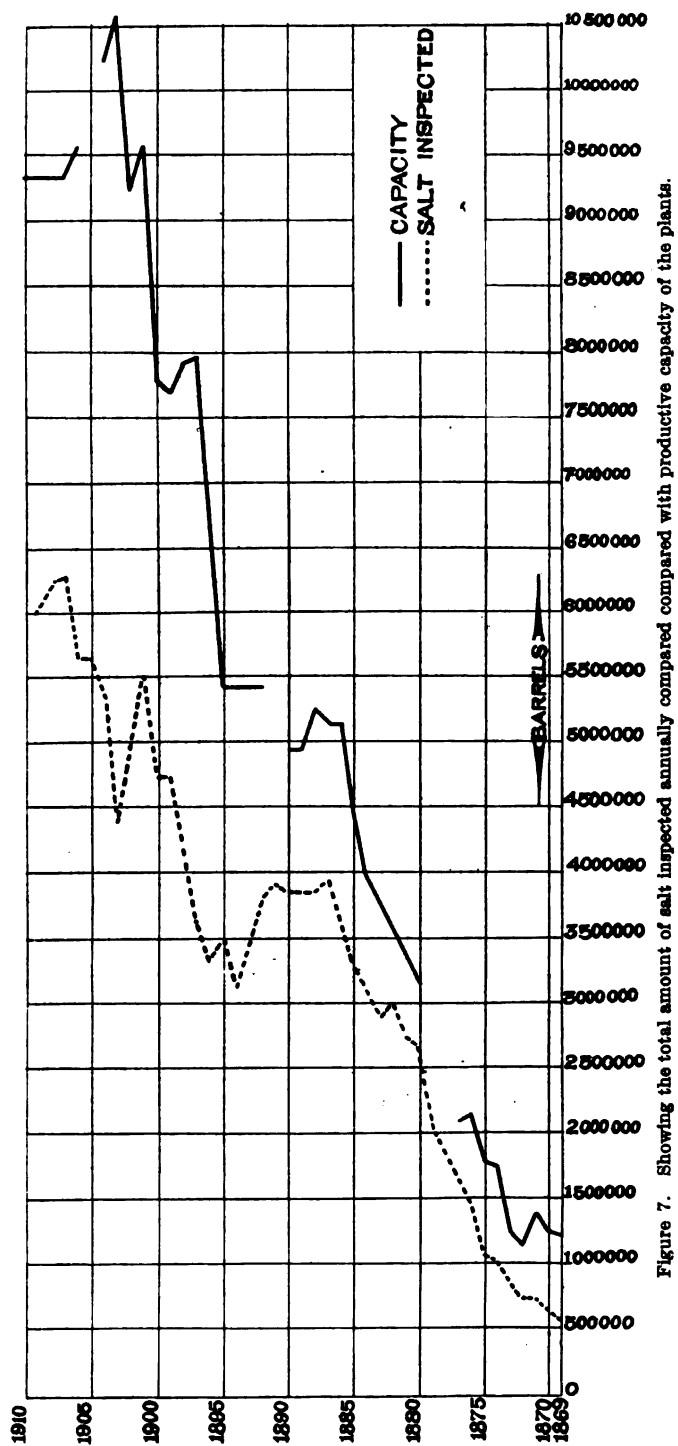


Figure 7. Showing the total amount of salt inspected annually compared with productive capacity of the plants.

With Fig. 6 in mind, it is interesting to turn now to Fig. 7 in which is represented the amount of salt inspected annually together with the estimated capacity of the blocks in the state. We see here, that in spite of the decrease in the number of companies and blocks since 1887, there has been an almost continuous increase in the capacity of the blocks. This has been due very largely to the opening of the Manistee, St. Clair, Ludington and Wayne districts, in 1881, 1883 and 1885 respectively, with their large grainer plants, and the introduction of the vacuum pan (See Fig. 6.). Fig. 7 also brings out the fact that the capacity of the various plants has always been considerably in excess of the output, in some instances the output being less than fifty per cent of the capacity.

The more local phases of the history of the industry have been reserved for later discussion, and will be treated under the several districts.

CHAPTER II.

THEORIES OF THE ORIGIN OF SALT AND BRINE DEPOSITS.

SALT DEPOSITS.

The question of the origin of salt deposits has long been a subject for discussion. Different modes of formation have been assigned to different deposits at the same time and the same deposits at different times. All of the theories thus far advanced can, however, be grouped under three general classes, namely,—volcanic, evaporation and the “Dome.”

Volcanic theories. Since until comparatively recent times, volcanism has been called upon to explain many different phenomena, it is not strange that the earlier theories of the origin of salt deposits should have made use of this geological process; especially is this true, since as early as 1826, Daubeny¹ announced the presence of hydrochloric acid and sodium chloride in the emanations of volcanoes. Thus Darwin² in discussing the deposits of salt on the island of San Lorenzo, off the coast of Peru, says, “The origin is in some way connected with volcanic heat at the bottom of the sea.” Although publication was not made until 1852, Ballaert³ conceived of the volcanic origin of salt in the Andes in 1826, and in his article on the classification and distribution of salt deposits, speaks as follows:

“In North and South America there is abundance of rock salt. In the north, among other ranges affording it, is the Wha-sacht, which is above the Great Salt Lake of Utah or of the Mormons; in South America, from the Andean region to the coast, on either side it is found, and in company with many other curious saline bodies.”

“From the small percentage of saline matter in sea-water, not 4 per cent, we can hardly look to the ocean as the origin of *so much pure or almost pure* chloride of sodium existing in mountain regions, but rather to sources of a volcanic character at different epochs; sub-marine as well as sub-aërial volcanoes yielding it. During volcanic eruptions, with vast quantities of sulphur and other volatile bodies, the vapor of muriatic acid escapes, and salt has been found sublimed about craters as well as muriate of ammonia. Sea-water may find its way into the igneous interior of the earth; however, the formation of salt in all

¹Daubeny, Charles, *Volcanoes*, London, 1826, pp. 168-172.

²Darwin, Charles, *Geological Observations*, London, 1842, Vol. III, p. 235.

³Ballaert, William, *Proc. Brit. Assoc. Adv. Sci.*, 1852, part 2, p. 100.

probability is mainly due to the direct union of chlorine and sodium; salt thus formed from its elements in the bowels of the earth, then ejected through volcanic vents, at times with steam and water as a hot saturated solution, at times with earthy matters, the salt afterwards forming masses, or in those peculiar orbicular layers, as seen in Cheshire and elsewhere, and such operations having gone on at various periods and under different circumstances and elevations, may account for rock or fossil salt being now found below the level of the sea, above it, and at great elevations on the surface of the globe."

The above named authors based their conclusions not only upon the known presence of hydrochloric acid and sodium chloride in volcanic emanations, but also upon the elevation of the deposits above sea level and their associations with igneous rocks. From certain laboratory experiments upon the action of clay and water vapor upon fusion mixtures of various salts, Gorgeu⁴ found that sodium iodide and magnesium chloride disappeared very rapidly. He concluded from this that salt deposits formed from igneous eruptions should be characterized by the absence of these compounds, and on this basis would assign to the deposits at Dieuze, France, an igneous origin.

Numerous other writers have advanced different volcanic theories, all of which would fall into the following classification given by Hubbard⁵:

- "1. The compounds were brought up from the interior of the earth in the form of molten masses, like ordinary extrusive rocks.
2. The compounds were formed by the action of gases, either by sublimation or by the alteration of materials in place.
3. The compounds were formed in a concentrated solution in hollows in the earth's crust and either solidified after the manner of granite or were extruded through fissures like porphyries.
4. The compounds were ejected as a slime after the manner of mud volcanoes."

However, with the possible exception of the case of deposits so small as to be of no economic importance, the various volcanic theories have been displaced by the evaporation theories and, therefore, need not claim our further attention.

Evaporation theories. It was early recognized that certain salt deposits were formed by the evaporation of saline waters. The general application of this mode of formation, however, met with two apparently great obstacles: the enormous thickness of some of the deposits in comparison with their other dimensions, and their great elevation above sea level. The latter objection was not really a serious one in the light of some of the now known great diastrophic movements,

⁴Gorgeu, Alexander, *Comp. rend. l'Acad. des Sci.* 102, p. 1165.

⁵Hubbard, L. L., *Geol. Sur. Mich.*, Vol. V, part II, p. xii.

and the recent explorations in arid regions which have disclosed enormous deposits undoubtedly formed from saline waters having no connection with the ocean.

The first evaporation theory which, although not without objectors, explained deposits of such great thickness, is the one known as the "Bar" theory. This theory probably owes its inception to G. Bischof⁶, although his conclusions were based upon erroneous data⁷. However, twelve years later, it was so forcibly readvanced, with certain modifications, by Ochsenius⁸ that it is commonly known by his name.

The "Bar" theory⁹ supposes a basin or arm of the sea, the entrance of which is partially closed by a bar which may have been originally present or may have been formed by the winds and currents pushing up the sand until the entrance is nearly closed. In order that the process of deposition may go on, this bar must be of such a height that the influx of water from the sea will not be greater than the loss of water due to evaporation at the surface of the bay, and also of sufficient height to prevent the action of outward sub-surface currents. It has been pointed out by Wilder¹⁰ that the reason for the non-formation of salt deposits in the Mediterranean Sea is the fact that the bar which separates it from the Atlantic Ocean is not of sufficient height to prevent outflowing sub-surface currents, so that although evaporation is more rapid in the Mediterranean than in the Atlantic, as is shown by a specific gravity of 1.028-1.03 for the former in contrast to 1.026 for the latter, a concentration sufficient to cause deposition of the salts in solution is not reached.

On account of the shallower depth of the bay, evaporation goes on more rapidly than in the open sea, and furthermore, the surface is not disturbed to the same extent by winds and currents. Therefore a more concentrated layer is formed at the surface, which, on account of its higher specific gravity, sinks, producing an increase in concentration with depth until the saturation point of the solution with respect to some compound is reached and that compound is deposited.

The order of deposition and the nature of the compounds formed have long been the subject of research. In 1849, Usiglio¹¹ published his oft-quoted experiments upon the evaporation of sea water. Still

⁶Bischof, G., *Lehrbuch der Chem. u. Physik. Geologie*, 1864, II, p. 48.

⁷Walther, Johannes, *Centr. fur Min. Geol. u. Pal.*, 1903, p. 211.

⁸Ochsenius, C., *Die Bildung der Steinsalzlager u. s. v.*, Halle, 1877: *Chem. Zeit.*, 1887, II, pp. 848, 935, and 962; *Proc. Acad. Nat. Sci., Phila.*, 1888, p. 181.

⁹The substance of the theory is summarized by Ochsenius (*Die Bildung u. s. v.*, pp. 11-12.) in the following paragraph:

"Meeresbusen mit hinlänglich bedeutender Tiefe in Innern und einer annähernd horizontalen Mündungsbarre, welche nur so viel Meereswasser eintreten lässt, als die Busenoberfläche auf die Dauer zu verdunsten im Stande ist, liefert (ohne anderweitige Communication) unter vollständig oder nahezu anhydrosischen Verhältnissen ein Salzlager, dessen Mächtigkeit nur von Busentiefe und der Dauer der obwaltenden Mstände abhängt."

¹⁰Wilder, Frank A., *Jour. Geol.*, Vol. II, p. 742, 1903.

¹¹*Ann. de Chim. et de Phys.* (3) Vol. XXVII, 1849, pp. 92, 172.

it was not until recently, through the researches of Van't Hoff¹² and others that the exact relationship has been established.

Van't Hoff¹³ states that there are five factors which determine the order of deposition and the compounds formed. These factors are: (1) composition of the solution, (2) solubility of the substances in solution, (3) time, (4) temperature, and (5) pressure.

While it might at first be thought that the least soluble substance would be the first deposited, and that the others would follow in the order of the least solubility, yet a moment's consideration shows that the most soluble salt might be present in such large amounts and the less soluble in so much smaller amounts, with regard to their saturation points, that the most soluble salt alone would be precipitated. The law upon which the progress of crystallization is based is given by Van't Hoff¹⁴ as follows: "In depositing its contents, the solution gradually varies its composition away from that of a solution which is saturated with the substance being deposited at the moment and contains nothing but this substance." The order of deposition is still further complicated by the formation of double salts, such as polyhalite (2CaSO_4 , MgSO_4 , K_2SO_4 , $2\text{H}_2\text{O}$) and carnallite (MgKCl , $6\text{H}_2\text{O}$).

In his experiments on the evaporation of sea water, Usiglio failed to obtain certain compounds which are formed in nature. Van't Hoff¹⁵ has shown that this is due to the neglect of the time factor. Owing to the fact that certain compounds tend to supersaturation and do not separate out as soon as their saturation point is reached, if the concentration process is carried on too rapidly these compounds may be broken up and new ones formed in their stead.

Van't Hoff¹⁶ has further shown that temperature also plays an important part in determining the nature of the compound formed. Thus certain minerals such as langbeinite ($\text{K}_2\text{Mg}_2(\text{SO}_4)_6$) and loewite ($\text{Na}_2\text{Mg}(\text{SO}_4)_2$) are formed only at temperatures above 37°C . for the former and 43°C . for the latter. This is especially significant in a consideration of salt deposits, since the presence or absence of certain minerals may give an indication of the temperature at which the deposits were formed.

The effect of pressure is the least important of any of the factors. Van't Hoff finds that it tends merely to raise the temperature of formation of the salts, and since the increment per atmosphere of pressure is very small, it would be effective in very few cases in producing pronounced changes.

In the case of the Dead Sea, we have the deposition of the sodium

¹²Sitzungsber. der Königl. preuss. Acad. der Wissensch., von 1897 an.

¹³Physical chemistry in the Service of Science, p. 100.

¹⁴Ibid. p. 104.

¹⁵Ibid. pp. 115-118.

¹⁶Ibid. pp. 120-121.

chloride alone, since the waters have not as yet reached the saturation point with respect to any other salt or combination of salts present. If the sea were to be shut off from the influx of new waters, it would eventually dry up and all of the material in solution would be deposited. The order of deposition under such conditions could be foretold by the method of Van't Hoff.

As a rule, we find the first substance which has been deposited is calcium carbonate. Usiglio¹⁷ found by the evaporation of sea water that there are two depositions of the carbonate, one at a specific gravity 1.0506, which begins gradually and ends suddenly, and a second at 1.1304, which begins suddenly and ends gradually. This second precipitation is believed to be due to the double decomposition between calcium sulphate and sodium carbonate. Usiglio's experiments further showed that between specific gravities 1.1304 and 1.22, 83.82 per cent of all the calcium sulphate was deposited; after this, 54.17 per cent of the sodium chloride was deposited with the balance of the calcium sulphate; and then, 8.5 per cent of the sodium chloride content without contamination. This is followed by the deposition of the sodium chloride with the more soluble salts in various combinations.

We find calcium sulphate associated with salt deposits in two prominent forms, gypsum ($\text{CaSO}_4, 2\text{H}_2\text{O}$) and anhydrite (CaSO_4). It is possible that one form has been derived from the other, either by hydration or dehydration, or that both are original and were deposited under different conditions. If secondary alteration of one to the other has taken place, this alteration should be recognized by the disturbance within the rocks caused by the great volume changes which would accompany such an alteration. Since in a great many, if not the majority of the cases, no such disturbance of the beds is apparent, it would seem that both substances are original deposits.

As to the conditions governing the form in which the calcium sulphate is deposited, there has been a considerable diversity of opinion.

Ochsenius¹⁸ found that in the case of the great German deposits the first deposit of calcium sulphate was in the form of gypsum and that the salt deposit was capped by anhydrite. He explained the deposition of the anhydrite as being due to deposition in a concentrated solution of deliquescent salts which extracted the water of crystallization from the gypsum as it passed through the solution.

Pfeiffer¹⁹ had a somewhat different idea of the formation of the anhydrite beds. He considered that the calcium sulphate was deposited as gypsum and that the sodium chloride deposited upon it withdrew the water of crystallization and changed it to anhydrite, after which,

¹⁷Loc. Cit.

¹⁸Loc. cit.

¹⁹Quoted by Ochsenius, Chem. Zeit. 1891, 15, No. 53.

the sodium chloride was redissolved and the process repeated until the bed had been formed.

Vater²⁰ has shown, however, that, at ordinary temperatures, anhydrite is not formed in saturated solutions of either sodium or magnesium chlorides, even in the presence of anhydrite.

Merrill²¹ suggests that whether the deposit is to be gypsum or anhydrite "may depend upon the amount of pressure and consequently upon the depth of the enclosed basin for it is estimated that a pressure of ten atmospheres is sufficient to cause sulphate of lime to crystallize as anhydrite."

Lane²² also considers pressure as the possible factor in the production of anhydrite. He calculates the specific gravity of the gypsum substance to be greater in the form of anhydrite and water than in the form of gypsum and therefore more condensed. From which he draws the following conclusion: "Therefore pressure would tend to aid its (anhydrite)²³ formation or change it into the former (anhydrite) shape."

The pressure theory was first advanced by G. Bischof in the first edition²⁴ of his *Lehrbuch der chem. u. physik. Geologie*. However, he omits all mention of it in the second edition²⁵, thus seeming to doubt its effectiveness. Also Spezia²⁶, in 1886, showed experimentally that of itself a pressure of 500 atmospheres was not sufficient to cause the formation of anhydrite. Furthermore, as already pointed out, Van't Hoff²⁷ considers that the only effect of pressure in determining the order of deposition and compounds formed, is its effect upon the temperature at which a compound will form. The increment per atmosphere²⁸ is so very small (a few thousandths of a degree) that it can scarcely be considered the important factor in the formation of anhydrite.

Van't Hoff and Weigert²⁹ have further shown that when the water-tension of the water in the gypsum becomes greater than that of the solution in which it is contained, the calcium sulphate will be precipitated as anhydrite. The water-tension of both the solution and water of crystallization increases with temperature but at different rates, so that in sea water the water-tension of the water of crystallization becomes greater than that of the solution at 25°C. and anhydrite is deposited. In a saturated salt solution, the temperature at which anhydrite formed was found to be 30°C., and in pure water, 66°C.

²⁰Vater, Heinrich, Sitzungsber. Akad., Berlin, 1900, p. 270ff.

²¹Merrill, F. J. H., Bull. N. Y. State Mus. Vol. 3, No. 11, 1893, p. 10.

²²Lane, A. C., Geol. Sur. of Mich. Vol. IX, Part II, p. 185.

²³The words in parentheses are the author's.

²⁴1855.

²⁵1864.

²⁶Spezia, G., Atti della R. Accademia delle Scienze di torino, 1886, 21, 20 Juni; abstract in *Zeitschr. für Kryst. u. s. v.*, 1888, 13, 302.

²⁷Loc. cit.

²⁸Van't Hoff, J. H., *Physical Chemistry in the Service of Science*, p. 123.

²⁹Van't Hoff, J. H. and Weigert, F., Sitzungsber. d. Akad. d. Ber. 1901, 2, s. 1140-48.

The interbedded clays and shales have been explained by Ochsenius as due to influxes of fresh water from the land surface, carrying fine particles in suspension. The fact that these layers are practically always clay or very fine sediments would seem to indicate the existence of a certain type of topography. In order that the evaporation might proceed with sufficient force to produce the deposition of salt, an arid or semi-arid climate is necessary. Since rains in an arid climate are generally of the "cloud-burst" type, unless the surface of the surrounding country were rather flat with the streams entering the basin with a small gradient, much larger particles would be carried in suspension by the water.

Walther's theory. Johannes Walther in his *Das Gesetz der Wüstungsbildung*¹⁰ has taken exceptions to the "Bar" theory. From his studies of the desert and the salt deposits there found, he is led to believe that too much emphasis has been placed upon laboratory experiment without proper consideration of climatic factors. Man, being an inhabitant of the more humid regions and almost entirely ignorant of the processes of the desert, has attempted to hypothesize conditions which would produce salt deposits in a more or less humid climate. Walther gives the conditions for the formation of salt deposits as follows:

1. A solution of any source and any concentration.
2. A desert climate with greater evaporation than precipitation.
3. A desert climate with strong insolation, occasional snowfalls and periods of cold, violent storms, wandering dunes, and driving dust.

As to the sources of the solution, it may have resulted from the cutting off of an arm of the sea; it may have its origin in the weathering and solution of igneous rocks; or it may be due to the solution of sea salts contained in marine sediments of former geological periods. In arid regions the rainwater sinks into the surface to a greater or less depth and is then returned to the surface by capillary action and is evaporated with the deposition of the salts in solution which are then subject to transportation by winds and succeeding rains.

The second factor mentioned above, i. e., the excess of evaporation over precipitation, is considered by Walther to be the controlling factor in the formation of salt deposits. He says that it makes no difference whether the evaporation occurs 400 meters below sea-level, as in the case of the Dead Sea, or at an elevation of 1500 meters, as in the case of Great Salt Lake; whether it is sea water spread out over a flat shore or in Thibet far from the ocean; and whether a flat sand bar separates a bay from the sea, or great bodies of saline river water are evaporated in small basins far from the sea.

¹⁰pp. 140-156.

The characteristic phenomena included under the third heading are believed by Walther to account for certain features of salt deposits which, on the basis of laboratory experiments, are shown to require high temperatures or great pressure. In evaporating solutions in the laboratory heat is applied from below, whereas in nature the heat is applied to the evaporating surface. Also it has been found that certain compounds which in the laboratory require for their formation temperatures far higher than that of the water of any ponds, lakes, or seas, are produced also under the influence of low temperatures or great changes in temperature such as would result from the melting of snow in saline solutions. The fact that deposits of sodium chloride of great thickness and purity exist may be due to the action of traveling dunes which, advancing upon the salt lake or marsh, "suck up" by capillarity the mother liquor, upon the further evaporation of which, the salts therein contained are deposited in a disseminated condition and therefore subject to the play of the wind. This may carry the dunes on until a later rain redissolves the salts from the dunes and concentrates them in depressions between dunes, giving rise to deposits of mother liquor salts free from gypsum and sodium chloride. Thus we see that in desert regions there are other means of transportation for the salts than running water.

Ochsenius¹ in 1902 discussed the work of Walther and reiterated the importance of the bar. To which Walther replied² that the bar, as supposed by Ochsenius, is purely hypothetical, that it does not exist, nor has it been known to exist in nature; and that, moreover, it is a superfluous condition to the formation of salt deposits, aridity being the essential factor.

Clarke³ has also pointed out that deposits of great thickness might be formed without the existence of a bar. He supposes a large sheet of water to be cut off from the sea, forming a basin, in which there is a deep depression. By evaporation the concentrated waters would accumulate in the depression and a deposit of considerable thickness might be formed. As he says, "If the surface area of the depression were small in comparison with that of the original sheet of water, the depth of the deposit might be very great."

The Dome theory. The occurrence of salt in Louisiana, Texas, and some other localities is of such a type as to render its origin unexplainable by evaporation theories. These deposits are circular to elliptical in shape, with great thickness relative to the diameter. They are arranged along lines of jointing or faulting and apparently at the intersection of the joint or fault planes. Surrounding the salt mass are the

¹Ochsenius, C., *Centr. fur Min. Geol. u. Pal.*, 1902, pp. 551, 557, and 620.

²*Centr. fur Min. Geol. u. Pal.*, 1903, pp. 211-217.

³Clarke, F. W., *U. S. Geol. Sur. Bull.* No. 330, p. 176.

upturned rock strata, decreasing in age from the center outward. Thus is produced a doming effect which may or may not be apparent topographically.

It was early recognized that these facts could not be explained by any surface evaporation theory, and many suggestions as to their origin were advanced. None of these, however, seemed tenable until the present theory was put forth by G. D. Harris in 1907. Harris' theory was first suggested in Bulletin No. 5 and later elaborated in Bulletin No. 7 of the Geological Survey of Louisiana. Still later it was published in a more condensed form in *Economic Geology*, Vol. IV, No. 1, pp. 12-35. The data here given have been taken from these papers.

The theory may be thus stated in a general way. The deposits have been formed by the crystallization of salt from waters, which have dissolved the salt out of some lower stratum, ascending along joints or fractures in the rocks. As the salt waters have ascended, a decrease in temperature has resulted in the separation of the salt crystals, and the force exerted by the growing crystals has produced the doming effect in the superimposed strata.

The nature of the process and its progress may perhaps be better understood from Fig. 8. The upper series represents conditions where the overlying strata are composed of loose and friable material, the lower, the conditions where the deposition has taken place beneath a more rigid stratum.

As to the efficiency of the pressure exerted by growing crystals to elevate several thousand feet of gravel, sand, and clay, Harris points out that, on the basis of A. L. Day's⁴ experiments, which show that the linear force of growing crystals is of the same order of magnitude as the crushing strength of the crystal, the force exerted by salt crystals from this region would be sufficient to raise sand, clay, and salt layers to a thickness of 3000 to 4000 feet. Furthermore, on account of the lower specific gravity of the salt, when it had once started to form it would continue along the same vertical line, which would be the line of least resistance.

BRINE DEPOSITS.

Natural brines are found in the more porous rocks, especially the sandstones. As to the origin of these brines there are two possibilities. They may be the original sea water in which the rocks containing them were laid down, or they may have been formed through the solution of salt by percolating waters.

Brines from original sea water. While it is not probable that many deposits from original sea water exist at the present time except at the

⁴Proc. Wash. Acad. Sci., Vol. VII, 1905, pp. 283-288.

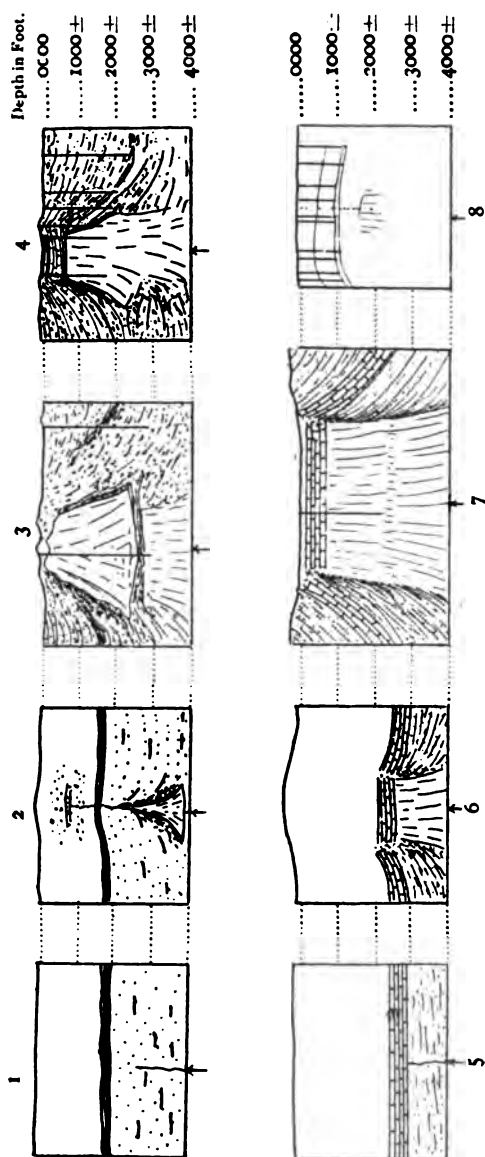


Figure 8. Figures representing the origin of dome structure by crystalline growth. (After Harris.)

surface of the lithosphere, yet it is conceivable that such deposits might be formed. A change from coarse to fine in the materials deposited in a basin cut off from the sea might imprison the sea water contained in the pore spaces of the coarser material, provided an impervious layer was also present below to prevent the circulative action of ground water. It may also be considered as a possibility that the waters of a desert sea which had an impervious substratum might be buried by wind blown material and thus preserved.

Brines from solution. In the consideration of brines formed from solution by percolating waters, a number of possible variations arise. In the first place, the salt from which the solution is produced may occur either in the form of concentrated deposits or disseminated throughout the rocks in which it is found. In the second place, the deposits may occur in the brine-bearing stratum or they may be present in some other stratum and the brine bearing layer act merely as a reservoir or conduit for the brine after it has been formed. And in the third place, the movement of the percolating waters may be downward, upward, or lateral.

The possible difficulties in the determination of the exact origin of a brine formed by solution are made manifest by the consideration of these various factors.

If the salt is in the form of a concentrated deposit or deposits, they may be of so small relative proportions that it would be extremely difficult to find them. On the other hand, the presence of disseminated material would be shown only by accurate chemical analyses. The difficulty is here increased by the second factor mentioned, that is, that the source of the material may be far removed from the brine-bearing stratum. As a rule, rock salt deposits are associated with limestones and shales. Therefore if the brine-bearing stratum be a sandstone, it is most reasonable to suppose that the deposit from which the brine has been formed is not within the brine-bearing layer. However, this is not necessarily true.

The direction of the water movement is determined by the texture and structure of the rocks and also by the nature of the forces producing the circulation.

The forces producing circulation which we shall consider are gravity and molecular attraction, or capillarity. The tendency of gravity is to cause a downward movement of water. However, the texture and structure may so act as to produce lateral and also upward movements of water. Capillarity, on the other hand, tends to produce movements from areas of greater concentration to areas of less concentration. While both of these forces may be acting at the same time, the pre-

dominance of one or the other will depend very largely on the texture of the rocks.

The texture of the rocks determines not only the porosity or water-holding capacity of the rocks, but also the perviousness or the ability of the rock to transmit water, the latter being the more important in this connection. The perviousness of a rock depends both upon the total amount of pore space and also upon the size of the individual pores. It is therefore a relative property. The larger and more continuous the individual spaces the more readily will gravitational water be transmitted. Conversely, as they decrease in size the movement due to gravity will be slower until a diameter is reached at which it will cease and any further movement must be due to capillarity. A stratum, therefore, in which the pore spaces are all of capillary or sub-capillary size would be relatively impervious, although its porosity

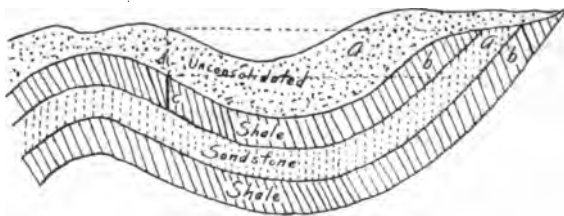


Figure 9. Showing a pervious stratum of rock between two impervious strata.

might be much greater than that of a more pervious stratum. We have all noticed how, after a rain, the water will form puddles in a heavy clay soil while in the case of a sandy soil it rapidly disappears. This is due to the fact that while the porosity of the clay may vary from 50 to 70% (the sand having a porosity of 30 to 40%) the individual pore spaces are so small that it is comparatively impervious.

The structures which are important in the control of underground circulation are those resulting from fracturing and folding. Fracturing, which produces fissures, joints, bedding partings and the like, opens up large channels for the transfer of gravitational water. The direction of the movement will depend upon the direction of the opening and the head under which the water is flowing. Folding results in throwing the strata which were originally horizontal into a series of folds, the concave portions of which are called synclines, and the convex, anticlines. If a series of strata composed of alternating pervious and impervious layers of rock be so folded and then exposed to erosion we shall have the layers successively exposed at the surface. Rain falling on their upturned edges will pass downward in the more pervious layers due to gravity, while the less pervious layers act in determining

the exact direction of the flow. If at any point having a lower elevation than the catchment area (the area from which the water is derived) an opening occurs in the impervious stratum above the pervious layer, the water will flow upward through this opening due to the head. These conditions are shown in Fig. 9, in which (a) represents the pervious strata, (b) the impervious stratum, (c) the fracture in the impervious layer, and (d) the head.

In order to determine which of the above theories are applicable to the salt and brine deposits of Michigan, it is first necessary to consider the geology and nature of the deposits, and we shall therefore turn our attention to that phase of the subject.

CHAPTER III.

GEOLOGY OF THE SALT AND BRINE DEPOSITS OF MICHIGAN.

INTRODUCTION.

While solid rock outcrops in a few places, the southern peninsula of Michigan is in general covered with a mantle of drift, or material transported and deposited there by the great glaciers which formerly covered the region. These deposits are made up of till, or boulder clay, sand and gravel. They vary greatly in constitution and also in depth, a thickness of about six hundred feet being found in the region of Manistee. Our knowledge of the geology of the southern peninsula is therefore based very largely on the records of deep wells.

It has been pretty definitely established that the lower peninsula has been a more or less persistent, and in later geological times isolated, basin of deposition since at least Middle Ordovician times. Lane¹ considers this basin to have existed in the Pre-Cambrian shield which passes from Wisconsin around through Northern Michigan into Canada. That minor oscillations have occurred is shown by the disconformities² between the Salina and the Niagara, the Lower and Middle Monroe, and the Middle and Upper Monroe. There has also been some minor folding as Lane³ has pointed out in the case of an anticline trending north-northwest from Saginaw, the Stronach anticline, the trend of which has not been determined, and other folds.

For our purposes, however, the different rock layers of southern Michigan may be compared to a pile of evaporating dishes cut across the top so as to present a surface of more or less concentric rings. This arrangement of the outcrops of the various strata with the superincumbent drift mantle removed may be seen at a glance from Fig. 10. A cross-sectional view of the basin is shown in Fig. 11 which represents a section on a northwest and southeast line across the center of the basin. An examination of the rocks themselves shows that they are composed of alternating beds of limestone, shale, and sandstone.

¹Lane, A. C. Notes on the Geological Section of Michigan. Geol. Sur. Mich., Ann. Report, 1908, p. 43.

²This term has been proposed by Grabau for unconformities showing no discordance in bedding.

³Lane, A. C., Geol. Sur. Mich., Vol. VIII, Part II, p. 176; Ann Rpt., 1901, p. 211; *ibid*, 1903, p. 291.

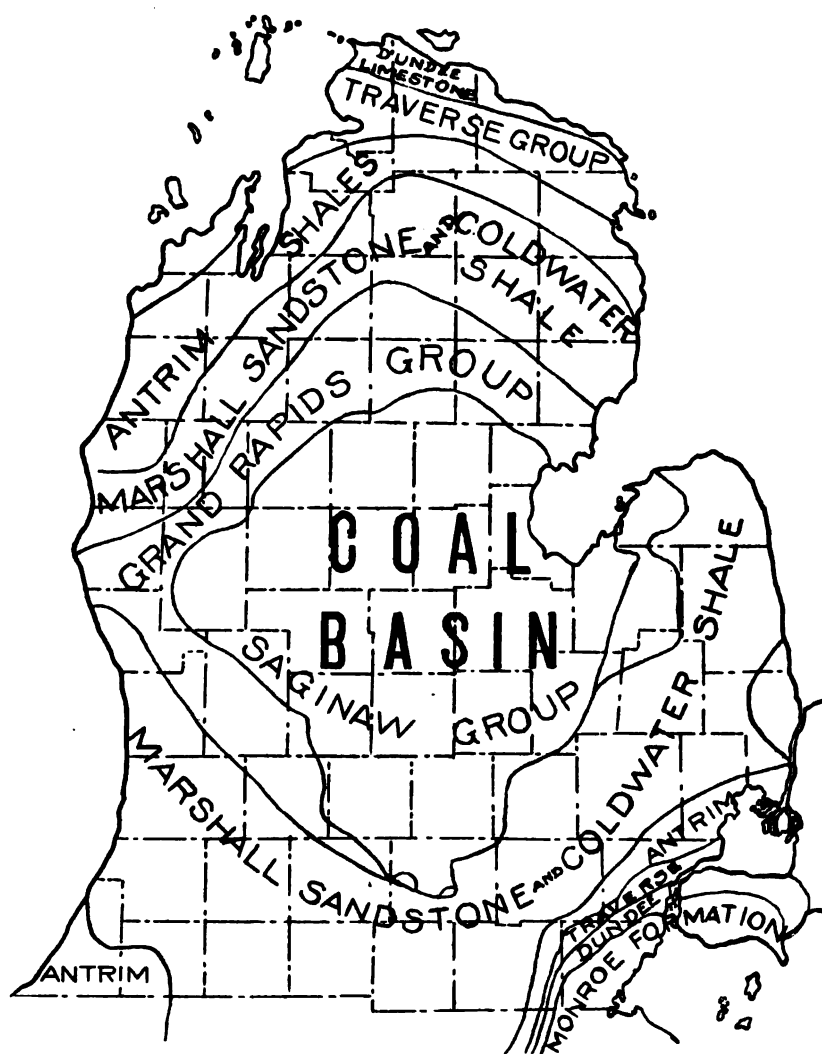


Figure 10. Outline geological map of the Southern Peninsula of Michigan.

System
QUATERNARY
POSSIBLY LATER

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It is not the purpose of this paper to consider the complete stratigraphy of the state, inasmuch as it has recently been very ably discussed by Dr. Lane⁴. Certain formations however, on account of their being the repositories of the brines and rock salt, demand our

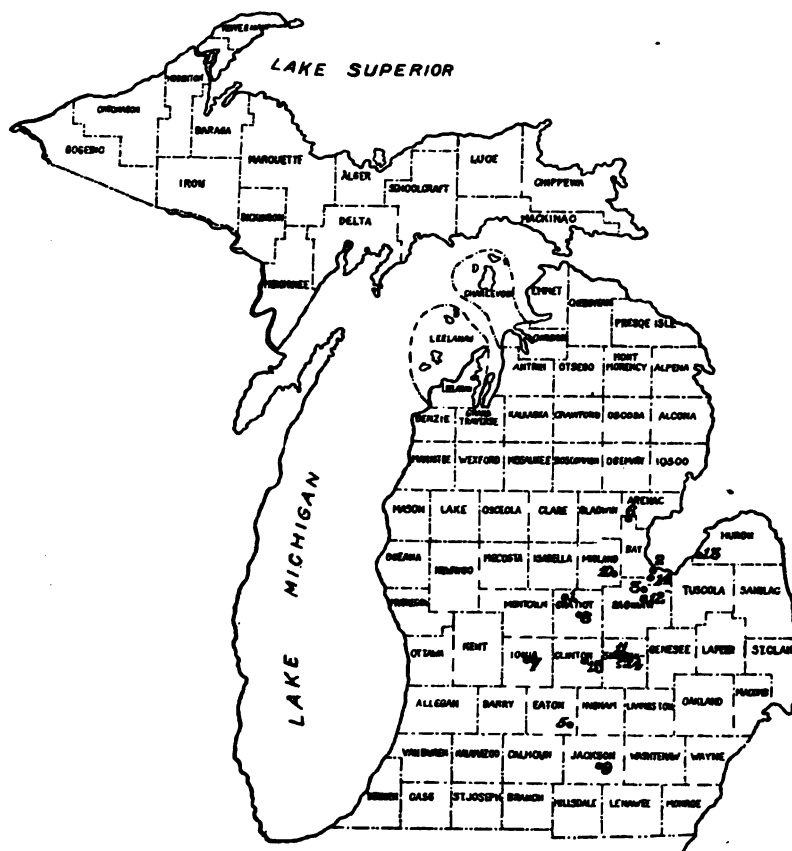


Figure 13. Showing the location of wells which enter the Parma sandstone.

- | | | |
|------------------|--------------|---------------------|
| 1. Alma. | 6. Garfield. | 11. Owosso. |
| 2. Bay City. | 7. Ionia. | 12. Saginaw. |
| 3. Carrollton. | 8. Ithaca. | 13. Sebawaing. |
| 4. Corunna. | 9. Jackson. | 14. South Bay City. |
| 5. Eaton Rapids. | 10. Midland. | 15. St. Johns. |

consideration. Of these, five⁵, the Parma, Marshall, Berea, Dundee, and Monroe are brine-bearing. The Salina, is the source of the rock salt of Michigan.

⁴Geol. Sur. Mich., Ann Rpt, 1908, pp. 1-91.

⁵The position of these beds is shown in Fig. 12.

TABLE II.⁹
Wells in the Parma sandstone.

Locality.	Approx. alt. of top of well.	Total depth of well.	Depth to Parma.	Thickness of Parma.	Approx. alt. of top of Parma.	Remarks.
Alma, Mich.	755	2861	710	80	+45	.....
Bay City, Mich.	592	2865	585	50	+7	.....
Carrollton, Mich.	590	750	375	55	+215	.....
Corunna, Mich.	776	907	231?	.....	+545	Parma and Marshall indistinguishable.
Eaton Rapids, Mich.	.....	.....	116	.....	.....	.....
Garfield, Mich.	.....	.....	400±	50±	.....	.....
Ionia, Mich.	.....	343	246	86	.....	.....
Ithaca, Mich.	.....	613	525	86	.....	.....
Jackson, Mich.	928	2455	88	292	.....	.....
Midland, Mich.	608	1305	810	110	+830	.....
Owosso, Mich.	745	1000	250	223	.....	Dow well.
Saginaw, Mich.	590	715	340	153	+495	.....
Saginaw, Mich.	600	900	474	59	+250	Salina well, near P. M. bridge.
Sebewaing, Mich.	583	303	87	13	+126	Saginaw Plate Glass Co.
South Bay City, Mich.	585	3508	490	50	+506	Liken well, N. E. 1/4 Sec. 18.
St. Johns, Mich.	.....	608	468	72	+95	North American Chemical Co. Water works.

⁹For the location of the wells see Fig. 13.

THE PARMA.

Areal distribution. The Parma sandstone lies at the base of the Coal Measures and its areal distribution may be considered roughly as that given for the Coal Basin (Fig. 10). Lane⁶ estimates the area of the Coal Basin including the Parma to be eleven thousand two hundred and thirty-four square miles. That this entire area is underlain by the Parma is doubtful. It seems to be absent in certain wells, as for example at Kawkawlin, where Rominger⁷ reports limestone and gypsaceous shales at the depth at which the sandstone should be expected.

Structure. In general this formation dips toward the center of the basin and, therefore, is found at an increasing depth, as is shown in Table II, which gives the depths of the Parma at various points, together with its thickness. The large and rapid variations in thickness are probably due to the presence of erosional unconformities, both above and below the formation. The unconformity above the Parma is indicated by the absence of the Parma at certain points where it should be expected; while at other places, the Grand Rapids group below seems to be very thin, or even absent, so that the Parma rests upon the Marshall sandstone and is indistinguishable from it, as at Corunna⁸. This may indicate an erosional unconformity or it may be due to an overlapping of the upper beds.

Superjacent and subjacent strata. As is shown in Fig. 12, the Parma is directly overlain by the Saginaw formation, which is the coal bearing horizon of Michigan. Lithologically this formation is made up of a series of shales of various colors, sandstones, coal seams and occasional thin bands of siderite. Siderite is also present at times in the form of nodules together with pyrite and sphalerite. The record of the No. 4 well of the Saginaw Plate Glass Co.¹⁰ shows gypsum just above the Parma. This, however, is the only record of gypsum above the Parma which has come to my notice.

Below the Parma we find in general the Bayport, or Maxville, limestone. This formation which consists for the most part of limestone strata, often containing cherty nodules, with occasional beds of shale and sandstone, is generally less than 100 feet thick. In the area south of Corunna, including Durand and Howell, the correlation is not certain, but the Parma, if present, seems to be underlain by the Lower Grand Rapids or Marshall formations.

Lithological character. The Parma in Jackson County is described by Winchell¹¹ as "a white, or slightly yellowish, quartzose, glistening sandstone." He also states that it is firmly cemented. In well

⁶Lane, A. C., Geol. Sur. Mich., Vol. VIII, Part II, p. 143.

⁷Rominger, C., Geol. Sur. Mich., Vol. III, p. 98.

⁸Lane, A. C., Geol. Sur. Mich., Vol. VIII, Part II, p. 27.

¹⁰Geol. Sur. Mich., Ann. Rpt., 1908, p. 103.

¹¹Winchell, A., 1st Bian. Rpt. State Geologist, 1860, p. 112.

samples, it appears as a very white sandstone, in some instances tending to be conglomeratic. The pebbles, when present, are rather small and composed of milky quartz. That the cementation process has been carried on to an advanced degree is shown by the way in which the drill breaks the rock, the rupture in some instances taking place through the pebbles while the cement remains intact. As we pass toward the center of the basin the conglomeratic phase seems to disappear and Lane¹² believes that at the center of the basin the sandstone is probably replaced by shale. However, at Mt. Pleasant, which is the point nearest the center of the basin from which information is obtainable, the Parma is represented by 124 feet of pure gray sandstone.

The Parma brines. In as much as the brines from this horizon are no longer used in the manufacture of salt, our knowledge of their composition is of necessity based upon old analyses. Although the following analyses have been published before, they are thought to be of sufficient importance to warrant repetition at this time.

TABLE III.

	1.	2.	3.
Sodium chloride.....	152.674	125.315	196.92
Sodium sulphate.....			1.16
Calcium chloride.....	5.302	3.472	7.42
Calcium sulphate.....	3.961	4.884	1.45
Magnesium chloride.....	4.115	4.333	4.32
Magnesium bromide.....			0.13
Total saline matter.....	166.052	138.004	211.70

1. Gilmore well, Bay City, Mich. Depth of well, 505 feet. Analysis by Dr. C. A. Goessman, October, 1862. Brine 65 degrees by salinometer. Geol. Sur. Mich., Vol. III, p. 181. Ibid, Ann. Rpt., 1905, p. 389.

2. Portsmouth, Bay Co., Mich. Depth of well, 664 feet. Brine 54 degrees by the salinometer. Analysis by Dr. C. A. Goessmann, October, 1862. Geol. Sur. Mich., Vol. III, p. 182.

3. Bay City, Michigan. Well, unknown. Specific gravity, 1.163. Analysis by Jas. R. Clinton and Co., A. Winchell, Am. Jour. Sci., Vol. 34, p. 311, 1862.

It is to be regretted that our analyses of this brine are limited to such a small area, as they give no clue to possible variations in its composition. I think we are safe in assuming, however, that, as we pass toward the center of the basin, the earthy bases will increase relatively to the alkalis. The above analyses show that, although the Parma

¹²Lane, A. C., Geol. Sur. Mich., Ann. Rpt., 1908, p. 87.

brines are weaker than those of the Marshall and Berea formations, they are in general freer from earthy chlorides. They are also distinguished from the Marshall and Berea brines by a relatively larger percentage of calcium sulphate (gypsum).

Origin of the Parma brines. Winchell¹³ apparently considered that the brines of the Parma sandstone had their origin in the Saginaw formation, as he speaks of the first salt horizon as "the Coal Measures with the Parma sandstone as a reservoir." Hubbard¹⁴, on the other hand, has suggested that these brines might be the original sea water in which the sandstone was laid down or that they might have originated in the underlying saline beds. The latter hypothesis has also been advanced by Grimsley¹⁵ in discussing the origin of the gypsum deposits of Michigan. He thinks the most probable origin of the gypsum of the Grand Rapids series to be from deposition in an isolated sea. If, however, evaporation had been complete, a much larger amount of salt (sodium chloride) than of gypsum would have undoubtedly resulted. As far as our present knowledge goes, such a deposit of salt does not exist. Grimsley believes that the present absence of known salt deposits in the Grand Rapids series would not be hostile to the hypothesis, since, "the gypsum now remaining shows marked effects of solution and these effects would have been much greater in the salt. The salt laden waters would flow downward along the slope of the rock and percolating through would work up under hydrostatic pressure, as it approaches the center of the basin, into the overlying Parma sandstone which is more gypsiferous than the underlying Marshall."

As already noted, our knowledge of the Parma and its brines is very limited, so that any explanation of their origin can be but a tentative one at best. The points to be considered are as follows:

1. The presence or absence of salt beds within the Parma sandstone.
2. The composition of the brine.
3. The presence or absence of the required salts in the overlying and underlying formations.
4. The lithological character of the overlying and underlying formations.
5. The nature and distribution of the Parma sandstone.
6. Paleontological evidence.

As yet no deposits of rock salt or gypsum have been found within the Parma sandstone. It seems probable, therefore, that if the brine has been formed through the solution of such deposits, the deposits must be sought outside of the formation. A clue to the composition

¹³Loc. cit.

¹⁴Hubbard, L. L., Geol. Sur. Mich., Vol. V, Part II, p. 16, 1893.

¹⁵Grimsley, G. F., *ibid.*, Vol. IX, Part II, p. 190, 1904.

of these deposits is afforded by the composition of the brines. The Parma brines, as is shown by the analyses, are characterized by a high percentage of calcium sulphate relatively to the chloride. This would seem to indicate that the source of the brines must have contained a considerable amount of gypsum. Except in the one instance, already noted, gypsum has not been found above the Parma sandstone, and while this apparent absence may be due to our lack of knowledge, yet it would seem to argue against such an origin of the Parma brines as suggested by Winchell¹⁴. On the other hand, below the Parma, although generally separated from it by the Bayport limestone, is found the Lower Grand Rapids formation which contains large deposits of gypsum.

As to the lithological nature of the overlying and underlying formations, we have seen that the formation above the Parma (the Saginaw) is composed largely of shales, although exhibiting sandstone facies at some points. This would form an impervious stratum against the directly downward percolation of water, the movement tending rather along the bedding planes. The movement would therefore be toward the center of the basin, and the water would be under hydrostatic pressure so that it would be forced to rise whenever fractures were encountered. Conditions would be similar within the Lower Grand Rapids formation, so that the water entering at the upturned edges would tend to move toward the center of the basin, dissolving out the salts as it progressed, until fractures were found through which, on account of the hydrostatic pressure, it would be forced up into the Parma sandstone, where it would be retained by the impervious capping of the Saginaw formation above.

It has already been noted that the Parma sandstone is undoubtedly not continuous underneath the Saginaw formation. This patchy occurrence is not, however, entirely due to the deposition, as Lane¹⁷ has pointed out that an unconformity exists not only below but also above the Parma. This type of occurrence together with an erosion surface above makes it difficult to see how the brine might be original sea water as suggested by Hubbard¹⁸. Also the presence, as recorded by Winchell¹⁹, of calamites and sigillariae, plants intolerant of salt water, would seem to argue against either an original sea water origin or the presence within the Parma of rock salt in the concentrated form or in disseminated deposits.

While not conclusive, a careful weighing of the evidence therefore seems to indicate that the brines have been formed through the solution

¹⁴Loc. cit.

¹⁷Loc. cit.

¹⁸Loc. cit.

¹⁹Winchell, A., Geol. Sur. Mich., 1st Bian. Rpt., p. 114, 1860.

of sodium chloride and gypsum within the Lower Grand Rapids formation and that they have risen into the Parma sandstone.

THE MARSHALL SANDSTONE.

The Marshall formation was early studied by Professor Winchell²⁰. He first divided it into the Napoleon, which he placed at the base of the Carboniferous, and the Marshall at the top of the Devonian. Later²¹ he also placed the Marshall in the Carboniferous, uniting the Napoleon sandstone with it as the Upper Marshall. Finally he concluded there were no good grounds for separating the two. This later view was probably based on the fact that, in the Saginaw well, he found but one hundred and nine feet of sandstone before passing into the red shales, which, he says²², "must be regarded as the commencement of the argillaceous portion of the Huron group." Lane²³ has pointed out that this is probably not the case but that toward the center of the basin the sandstone of the Lower Marshall is replaced by shale which renders it indistinguishable from the next lower formation and that therefore there are good reasons for retaining the earlier subdivisions. While it is with the Napoleon, or Upper Marshall, that we have especially to deal, in considering the areal distribution, the formation will be treated as a whole.

Areal distribution. As may be seen from Fig. 10, the Marshall formation outcrops beneath the drift in a circular zone, five to forty miles in width, bordering the Grand Rapids group, except in the southeastern part of the state where it is in contact with the Saginaw formation. On the southern side of the basin, the boundary between the Marshall and the underlying Coldwater shales has been pretty well established from outcrops and well records. On the northern side however, the dividing line has not been definitely determined.

Structure. The general dip of the Marshall is toward the center of the basin, as is shown in Table IV²⁴. (The depths at which the Marshall is reached would seem to indicate, however, that the deepest part of the basin is not coincident with but north of the geographical center.) However, in his Huron County Report (page 96.), Lane says in regard to the top of the Marshall in Huron county, "It is thrown into a series of gentle folds pitching toward the northwest and corresponding in a general way to that slight fold which we have spoken of near Port Austin and to the fold in the coal mine at Sebewaing." This seems to conform to the fold at Saginaw which appears to cross the river near Carrollton, since in the Bliss well at Carrollton the Marshall is reached

²⁰Winchell, A., 1st Bian. Rpt., 1860.

²¹Winchell, A., Am. Jour. Sci., Vol. 33, pp. 352-356.

²²Report, 1860, p. 90.

²³Lane, A. C., Geol. Sur. Mich., Vol. VII, Part II, p. 92.

²⁴For location of the wells see Fig. 14.

at -60 A. T. To the north, the depth increases until at South Bay City it drops to -265 A. T. Likewise as we go south, the Marshall is reached in the Salina well, South Saginaw, at about -100 A. T., and at the Plate Glass Works at about -200 A. T.

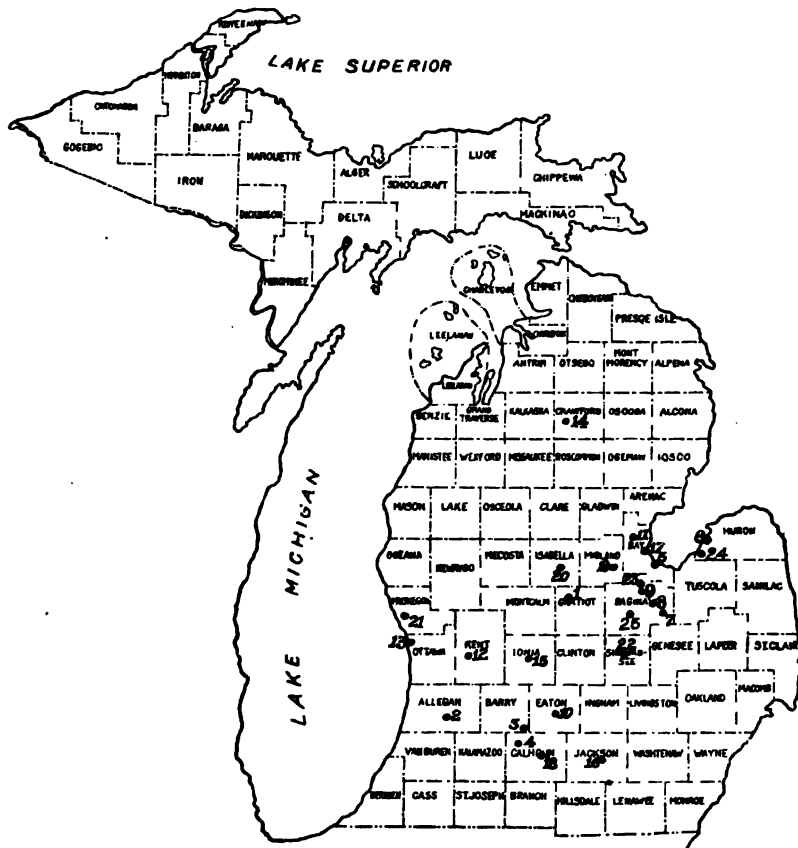


Figure 14. Showing the location of wells which enter the Marshall sandstone.

- | | | | | |
|------------------|----------------|-------------------|-------------------|------------------|
| 1. Alma. | 6. Bayport. | 11. Garfield. | 16. Jackson. | 21. Muskegon. |
| 2. Allegan. | 7. Blackmore. | 12. Grand Rapids. | 17. Kawkawlin. | 22. Owosso. |
| 3. Assyria. | 8. Bridgeport. | 13. Grand Haven. | 18. Marshall. | 23. Saginaw. |
| 4. Battle Creek. | 9. Carrollton. | 14. Grayling. | 19. Midland. | 24. Sebewaing. |
| 5. Bay City. | 10. Charlotte. | 15. Ionia. | 20. Mt. Pleasant. | 25. St. Charles. |

Superjacent and subjacent strata. Above the Marshall is a series of beds of shale, sandstone, and dolomite, with layers of gypsum, known as the Lower Grand Rapids or Michigan series. This group is of considerable interest in this connection on account of the persistence in it of the gypsum beds. Grimsley²⁵ states that, in the center of the basin,

²⁵Grimsley, G. P., Geol. Sur. Mich., Vol. IX, Part II, p. 97.

TABLE IV.
Wells in the Marshall (Napoleon).

Locality.	Approx. alt.	Total depth of well.	Depth to Marshall.	Thickness of Marshall (Napoleon).	Approx. alt. of top of Marshall.	Remarks.
Alma, Mich.	755	2861	1015	85	-260	.....
Allegan, Mich.	708	1400	255	76	+453	.....
Assyria, Mich.	917	.....	240	80	+677	.....
Bay City, Mich.	592	2865	830	90	-238	.....
Bay City, Mich.	585	3508	850	120	-265	North American Chemical Co.
Bay Port, Mich.	590	2000	270	135	+320	.....
Carrollton, Mich.	590	750	650	100	-60	Bliss well.
Charlotte, Mich.	906	2209	570	110	+536	.....
Corunna, Mich.	776	907	800?	.....	.....	G. S. M. Vol. V. Plate XII.
Garfield, Mich.	.....	.....	800	60	.....	.....
Grand Rapids, Mich.	605	2220	128	131	+477	Ibid, Plate XX.
Midland, Mich.	608	1305	1205	.....	-597	Dow Chemical Co.
Mt. Pleasant, Mich.	770	1550 +	1405	145 +	-635	.....
Owosso, Mich.	745	1000	556	45	+189	G. S. M. Vol. V. Plate XLV.
Saginaw, Mich.	590	715	690	.....	-100	Salina well.
Saginaw, Mich.	620	900	820	78	-200	Saginaw Plate Glass Co.
Sebewaing, Mich.	593	303	248	55	+345	Liken well. Still in Marshall.

the gypsum is replaced by anhydrite, or the anhydrous form of calcium sulphate. The general presence of gypsum or anhydrite in this formation is shown by the records of various wells,—thus at Saginaw (gypsum, 651-676; dolomite and gypsum, 735-743), Bay City (gypsum, 780-790), Midland (fairly pure anhydrite, 970-1050), Mt. Pleasant (anhydrite and dolomite, 1150-1250; anhydrite, 1250-1295), Grayling (gypsum, 408-540), and Alma (blue and white (anhydrite) gypsum, 860-895). We see, therefore, that during Lower Grand Rapids time physical and climatic conditions in the Michigan basin were such as to cause deposition of the substances in solution through evaporation. As far as our present knowledge goes, however, the process of deposition was not carried to the point at which the concentration of the solution with respect to the sodium chloride was sufficient to bring about a precipitation in large quantities.

Below the Marshall we find a series of blue and black shales known as the Coldwater formation. The gradation between the Marshall and Coldwater is such that the determination of the boundaries between them is extremely difficult. For our purposes however, the lower limit of the sandstone member of the Upper Marshall, or Napoleon, is a matter of more importance and is more easily determined, especially in the case of that portion of it which is brine bearing. Thus at both Saginaw and Bay City we find beneath the sandstone a red clay or shale. That the same is also true at Midland is shown by the record of the last well put down by the Dow Chemical Co. (See Fig. 40.) It is perhaps well to point out that the first appearance of this shale does not always indicate the base of the sandstone, as in some of the wells of the Saginaw Plate Glass Co. we find that the sandstone is split by 3-5 inches of red "marl." No samples of this "marl" were obtainable, but I take it to be red clay or shale.

Lithological character. The Napoleon sandstone is usually a whitish sandstone, at times possessing a greenish or bluish tinge. It is generally finer grained than the Parma, not so clean looking, and less well cemented. It is at times micaceous and often pyritiferous. In well samples grains of quartz are often found to be coated with limonite, probably formed from the decomposition of pyrite. I judge this to be the case because the limonite has not imparted a general coloration to the quartz as might be expected if it were originally present.

Marshall (Napoleon) brines. At the margin of the basin near the outcrops, the Napoleon is the source of fresh water in many wells. However, as we pass toward the center of the basin, the water becomes mineralized to such an extent that it has been, and still is, the principal source of the salt of the Saginaw valley.

A large number of analyses of the brines from the vicinity of Saginaw

have been published. An especially interesting series was prepared by Dr. Hahn.²⁶ These analyses were published originally in Germany and it is thought well to present a number of them in this connection.

TABLE V.

	4.	5.	6.	7.	8.
(²⁷)					
(Na, K) Cl.....	16.871	16.816	19.804	19.860	19.671
MgCl.....	1.774	1.156	1.343	1.261	1.381
CaCl.....	3.287	2.068	2.623	2.961	2.916
CaSO ₄	0.098	0.173	0.080	0.072	0.082
MgO, 2CO ₂					0.0015
CaO, 2CO ₂	0.050		trace		0.0010
FeO, 2CO ₂	0.0116		0.0054		9.0123
FeCl & FeCl ₃			0.0032		0
Na (?) Br.....	0.0401				
Free CO ₂			trace		trace
SiO ₂ & Al ₂ O ₃	0.0245				
SH.....			0		0
HO.....	76.844	79.847	76.269	75.846	75.715
Total.....	100.000	99.560	99.628	100.000	99.758

²⁷ The chemical symbols are taken directly from the original. Figures represent parts per hundred.

4. East Saginaw Co., No. 1 well. Depth of well, 730 feet. Specific gravity, 1.177. Analysis by Dr. Chilton.

5. New York and Saginaw Co., No. 3 well. Depth of well, 813 feet. Specific gravity, 1.1548. Dr. H. C. Hahn, analyst.

6. Oneida Co., Zilwaukee. Specific gravity, 1.1864. Dr. H. C. Hahn, analyst.

7. Bangor Co., Bangor. Depth of well, 844 feet. Specific gravity, 1.194. C. Goessmann, analyst.

8. Michigan Co., No. 1 well, Zilwaukee. Depth of well, 928 feet. Specific gravity, 1.1909. Dr. H. C. Hahn, analyst.

TABLE VI.

	9.	10.	11.	12.	13.
(²⁷)					
(Na, K) Cl.....	19.671	17.510	17.586	19.499	13.832
MgCl.....	1.335	1.069	1.210	2.033	0.945
CaCl.....	2.987	2.643	3.212	4.564	2.469
CaSO ₄	0.079	0.098	0.065	0.048	0.070
MgO, 2CO ₂	0.0016			0.003	
CaO, 2CO ₂	0.0009			0.0023	
FeO, 2CO ₂	0.0116			0.0213	
FeCl & FeCl ₃	0				
Free CO ₂	0.0056				
HO.....	75.477	78.680	77.927	74.401	82.684
Total.....	99.570	100.000	100.000	100.572	100.000

²⁶Hahn, Dr. H. C., Berg und Huettenmaenische Zeitung, 26, 1867, pp. 136-7.

²⁷The chemical symbols are taken directly from the original. Figures represent parts per hundred.

9. New York and Saginaw Co., No. 1 well. Depth of well, 959 feet. Specific gravity, 1.1739. Dr. H. C. Hahn, analyst.

10. Forest Valley Co., Saginaw City. Depth of well, 905 feet. Specific gravity, 1.173. C. Goessmann, analyst.

11. Chicago Co., Florence. Depth of well, 1,069 feet. Specific gravity, 1.165. C. Goessmann, analyst.

12. Wayne County Co., Tittabawassee. Depth of well, 1,142.5 feet. Specific gravity, 1.2045. Dr. H. C. Hahn, analyst.

13. D. H. Fitzhugh, Salsburg. Depth of well, 1,123.5 feet. Specific gravity, 1.133. C. Goessmann, analyst.

Other analyses from this area, but of more recent date, are given in Tables VII and VIII.

TABLE VII.

	14.	15.	16.	17.
Specific gravity.....	1.170	1.183	1.182	.....
Sodium chloride.....	179.12	222.46	167.30	228.00
Calcium chloride.....	21.42	48.10	41.10	45.00
+2H ₂ O.....	.....	14.68	.....	.....
Magnesium chloride.....	15.22	9.62	17.60	17.00
Calcium sulphate.....	1.16	0.884	.....	0.80
+2H ₂ O.....	.....	0.232	.....	.....
Potassium chloride.....	2.20	.....	.....	.....
Magnesium bromide.....	.....	0.200	0.712	0.3 to 0.1
Ferrous carbonate.....	1.05	.....	.....	0.15
Ferrous oxide.....	.....	0.259	.....	.....
Ferric oxide.....	.....	0.196	.....	.....
Ferrous chloride.....	.....	.....	0.05	.....
Ammonium chloride.....	.....	.....	.....	0.05
Silica.....	.....	.....	.....	0.02
Alumina.....	.....	.....	.....	0.02
Total solids.....	220.19	296.631	206.762	291.34

14. East Saginaw Salt Manufacturing Co., East Saginaw, Mich. Depth of well, 742 feet. Analysis by Professor Douglas, University of Michigan, April 16, 1860. (Geol. Sur. Mich., 1st Bian. Rpt., 1860, p. 171.) This was the first successful salt well in Michigan.

15. St. Charles, Mich. Depth of well, 810 feet. (Geol. Sur. Mich., Ann. Rpt., 1903, p. 107.)

16. Saginaw Salt Co., St. Charles, Mich. Analysis by J. C. Graves. Analysis furnished by the company.

17. Saginaw Valley brines. (U. S. G. S. Min. Res. 1908, Part II, p. 650.)

This is apparently a composite analysis.

TABLE VIII.

	18.*	19.*	20.†	21.†
Sodium chloride.....	234.05	141.00	13665.60	13270.88
Calcium chloride.....	32.90	83.00	2624.92	2629.69
Magnesium chloride.....	21.20	31.00	1004.85	1034.67
Calcium sulphate.....	0.80			56.06
Magnesium bromide.....			20.38	56.72
Magnesium sulphate.....			44.86	
Ferrous carbonate.....			8.96	
Ferric oxide.....		trace		
Alumina.....	0.05	trace		
Bromine.....		1. +		
Water of Combination.....			2174.80	
Total.....	289.00	256.00	19544.37	17042.02

*Grams per kilogram.

†Grains per gallon.

18. North American Chemical Co., Bay City, Mich. Depth of well, about 970 feet. Analysis by A. Llewellyn Allen. Furnished by M. L. Davies, general manager of the company.

19. Dow Chemical Co., Midland, Mich. Depth of wells, about 1,300 feet. Analysis furnished by Mr. Dow.

20. Saginaw Plate Glass Co., Saginaw, Mich. Well No. 1. Depth of well, 906 feet. Analysis by Professor F. S. Kedzie, Mich. Agr. Coll., August 8, 1905.

21. Same. Analysis by Professor E. D. Campbell, Univ. of Mich.

The following more recent analyses of Napoleon brines appeared in an article entitled, "Composition of the Salines of the United States" by J. W. Turrentine.²⁸

22. Bliss VanAuken Co., Saginaw, Mich. Composite brine from three wells, 80° by salinometer. 1911. R. F. Gardner, analyst.

23. Edward Germain, Saginaw, Mich. Brine from well No. 1, 750 feet deep, 1910. R. F. Gardner, analyst.

24. Mershon, Eddy, Parker and Co., Saginaw, Mich. Composite brines from two wells. R. F. Gardner, analyst.

25. S. L. Eastman Flooring Co., Saginaw, Mich. Composite brines from two wells. 1911. R. F. Gardner, analyst.

26. Saginaw Plate Glass Co., Saginaw, Mich. Composite brine from ten wells. 1911. R. F. Gardner, analyst.

27. Dow Chemical Co., Midland, Mich. Composite brine from ten wells. 1911. R. F. Gardner, analyst.

28. Dow Chemical Co., Mt. Pleasant, Mich. Composite brine from five wells. R. F. Gardner, analyst.

29. Saginaw Salt Co., St. Charles, Mich. Brine from one well. 1911. R. F. Gardner, analyst.

²⁸Jour. Industrial and Engineering Chem., Vol. 4, No. 12, Dec. 1912, p. 887.

TABLE IX.

	22.	23.	24.	25.	26.	27.	28.	29.	30.
Potassium.....	trace	0.4	1.4	0.8	1.0	trace	1.2	trace	trace
Sodium.....	77.8	100.0	129.7	78.2	86.6	69.3	52.5	85.5	111.5
Calcium.....	10.8	7.6	12.8	10.8	16.0	36.6	50.2	15.8	4.2
Magnesium.....	3.8	1.0	3.6	3.2	4.4	8.6	11.6	4.0	13.2
Chlorine.....	145.4	155.1	155.4	145.9	172.9	196.4	205.4	163.0	205.4
Sulphuric anhydride.....	4.2	2.4	26.0	2.2	1.2	1.2	0.6	0.6	1.8
Bromine.....	0.4	1.7	2.0	0.5	0.4	2.2	trace	2.0	2.8

	22.	23.	24.	25.	26.	27.	28.	29.	30.
Potassium chloride.....	trace	0.8	2.7	1.6	1.9	trace	2.3	trace	trace
Sodium chloride.....	197.3	239.6	242.8	198.4	219.7	175.8	133.3	217.0	233.2
Calcium chloride.....	24.0	18.3	35.4	27.4	42.9	99.8	183.0	42.9	9.4
Magnesium chloride.....	13.3	3.9	6.3	9.8	15.3	32.5	45.5	5.5	37.2
Sodium sulphate.....	.....	.....	39.7	.....	.....	.....	.....	.....	.....
Calcium sulphate.....	6.0	3.4	trace	3.1	1.7	1.7	0.9	0.9	2.6
Magnesium bromide.....	0.8	.....	4.0	1.2	0.9	2.7	7.8	4.6	6.5
Sodium bromide.....	.....	2.2	.....	.....	.....	.....	.....	.....	.....
Ferrous chloride.....	.....	.....	.....	.....	.....	2.3	.....	.....	.....

Conventional combinations.

30. Saginaw Salt Co., St. Charles, Mich. Plant No. 2. Composite brine from two wells. R. F. Gardner, analyst.

From the preceding analyses it may be seen that there is a decided increase in the percentage of earthy chlorides relatively to the sodium chloride as we go toward the center of the basin. This is shown especially well by comparing the analyses from Bay City, Saginaw, Midland, and Mt. Pleasant. In general there seems to be also an increase in the bromine content in the same direction. However, some of the analyses seem to contradict this view.

A comparison of Napoleon and Parma brines brings out a number of points of difference. The high percentage of bromine is especially characteristic of the Napoleon brines. As compared with the Parma brines those of the Napoleon are very low in gypsum, or calcium sulphate. On the other hand, they are relatively higher in the earthy chlorides. As these compounds, together with the magnesium bromide, are more soluble than the sodium chloride, they are concentrated in the mother liquor, or bittern, in the manufacture of salt.

In the early days of the salt industry, the bittern was thrown away. Later, attempts were made at some of the plants to utilize it in the manufacture of bromine. The decrease in the price of this article has, however, caused the abandonment of all of the by-product plants except those of the Saginaw Salt Co., so that at present it is manufactured only at St. Charles, Mt. Pleasant, and Midland.

Another product which is now being manufactured from the mother liquors is calcium chloride, which is present in quite large amounts, as will be seen from the following analyses, of bitterns resulting from the evaporation of Saginaw valley brines, as extracted from the scrap-book of Dr. S. S. Garrigues.

TABLE X.

	30.	32.	33.	34.	35.
Specific gravity.....	1.2271	1.2340	1.2432	1.2488	1.3061
Sodium chloride.....	142.03	122.28	106.85	89.89	28.06
Magnesium chloride.....	38.56	47.41	53.60	61.74	93.68
Calcium chloride.....	83.81	105.06	118.15	135.08	211.92
Calcium sulphate.....	0.23	0.23	0.34	0.21	0.07
Water.....	755.28	755.02	721.06	711.06	666.27
Total.....	1019.91	1020.00	1000.00	997.98	1000.00

A more recent set of analyses of bitterns from the Napoleon brines is given by J. W. Turrentine.²⁹

²⁹Loc. Cit. p. 888.

TABLE XI.

	36.	37.	38.	39.	40.	41.	42.
Potassium.....	1.3	1.6	4.2	2.6	10.2	1.2	trace
Sodium.....	66.1	83.3	72.2	76.1	42.1	52.5	60.9
Calcium.....	40.6	32.4	36.4	32.8	192.6	50.2	0.6
Magnesium.....	11.5	9.6	11.0	9.6	35.2	11.6	0.4
Chlorine.....	207.7	198.4	202.2	195.8	427.7	205.4	91.5
Sulphuric anhydride.....	0.4	trace	0.8	1.4	none	0.6	3.6
Bromine.....		4.4	3.3	2.2	trace	trace	4.3

Conventional combinations.

	36.	37.	38.	39.	40.	41.	42.
Potassium chloride.....	2.5	3.1	8.0	5.0	19.5	2.3	trace
Sodium chloride.....	167.5	211.6	198.4	193.0	106.9	133.3	147.2
Calcium chloride.....	111.8	89.6	99.8	89.1	532.6	138.0	1.7
Magnesium chloride.....	45.1	15.3	19.3	26.3	18.4	45.5	1.6
Sodium sulphate.....							5.3
Calcium sulphate.....	0.6	trace	1.1	2.0	none	0.9	trace
Ferric chloride.....						2.3	
Magnesium bromide.....		10.1	9.5	5.1	trace	trace	
Sodium bromide.....							5.5

36. Hine and Co., Bay City, Mich. Bittern from grainer, 5 day's evaporation. 1911. A. R. Merz, analyst.

37. Bliss VanAuken Co., Saginaw, Mich. Bittern from grainer, 5 day's evaporation. 1911. R. F. Gardner, analyst.

38. Edward Germain, Saginaw, Mich. Bittern from grainer, 14 day's evaporation. 1911. R. F. Gardner, analyst.

39. Mershon, Eddy, Parker Co., Saginaw, Mich. Bittern from grainer, 4 day's evaporation. 1911. R. F. Gardner, analyst.

40. Saginaw Chemical Works (Saginaw Plate Glass Co.), Saginaw, Mich. Bittern which has been evaporated to 8.5% of the volume of the original brine, before the final evaporation for the preparation of calcium chloride. Samples taken while hot. On cooling a crystalline solid separated which contained 1.1% potassium, or 2.3% potassium chloride. 1911. R. F. Gardner, analyst.

41. Dow Chemical Co., Mt. Pleasant, Mich. Bittern after the removal of bromine. Contaminated with iron compounds. 1911. R. F. Gardner, analyst.

42. Saginaw Salt Co., St. Charles, Mich. Bittern, 4 day's evaporation. 1911. R. F. Gardner, analyst.

Origin of the Napoleon brines. According to Winchell,¹⁰ the brines of the Napoleon sandstone were formed through solution within the "Michigan Salt Group" or Lower Grand Rapids formation and the Napoleon sandstone served merely as a reservoir for the brines. That this hypothesis is scarcely tenable is shown by a consideration of the

¹⁰ Loc. cit.

composition of the brines themselves. From an examination of the analyses given above, it will be seen that these brines are characterized especially by their low gypsum content. As already pointed out the Lower Grand Rapids formation contains massive deposits of gypsum, whereas, so far as is known, no deposits of rock salt exist within the formation. If the Napoleon brines had been formed within the lower Grand Rapids formation through the solution of *disseminated* salt, it is scarcely conceivable that the gypsum which is present in vastly greater amounts should have been so slightly attacked.

The possibility of the source of the Napoleon brines being within the Lower Marshall or subjacent formations also seems remote inasmuch as the presence of large numbers of fossils, not tolerant of highly saline solutions, within the former would argue against the occurrence of either rock salt or disseminated deposits, while the brines of the latter as a rule show a much higher gypsum content than do those of the Napoleon.

It would seem, therefore, that the source of the brines must be sought within the Upper Marshall. The writer is of the opinion that the Napoleon brines are formed by the solution of disseminated salt within the red shale underlying the sandstone member. Whether this shale represents the upper portion of the Lower Marshall or is the seaward phase of the lower portion of the Upper Marshall (Napoleon) may be a debatable question but he favors the latter view, since we find that at Bay City the characteristic sandstone member has decreased to about one half the thickness which it exhibits in Huron county. Here it is succeeded by one hundred feet of red sandstone, instead of shale, which Cooper²¹ is inclined to include with the Upper Marshall.

The possibility of such an origin as mentioned above is demonstrated by the red shale sample from the No. 13 well of the Dow Chemical Co., Midland. This sample represents the formation at a depth of 1,390 feet. It is a very red, argillaceous shale and contains disseminated salt crystals which are visible to the naked eye. In order to prove that these crystals were not due to crystallization from the brine contained within the pore spaces of the shale, the following simple experiment was performed.

A 5 gram sample of the shale was treated with about 100 c.c. of distilled water, boiled about three minutes and filtered. The residue was then treated again in the same way with 50 c.c. of distilled water, the filtrate added to the first filtrate, and the residue washed with distilled water until the volume of the solution amounted to about 200 c.c. The solution was then placed on a water bath and evaporated to 30 c.c., when, on being cooled to room temperature, a very pronounced deposition took place, indicating supersaturation. Inasmuch as the

²¹ Cooper, W. F., Geol. Sur. Mich., Ann. Rpt., 1905, p. 154.

volume of water contained in the pore spaces of the clay could not exceed 12.5 c.c. if the pore space equalled 100 per cent. (taking the specific gravity at 2.5), it will be apparent that a portion of the salt must have been present as a disseminated deposit within the shale. While the absolute presence of disseminated salt in this one instance may not be sufficient to prove conclusively the origin of the Napoleon brines, yet when considered in connection with the improbability of their source lying either in the overlying or underlying formations, together with the lateral continuity of the Napoleon sandstone and the fact that the sample was obtained from the deeper part of the basin, it would seem to make such an origin extremely probable.

The facts of which account must be taken in considering this portion of Michigan's geological history are as follows: The general absence of fossils in the Upper Marshall, their abundance in the Lower Marshall, the fact that the fossils of the latter do not as far as known show any changes in form which might be expected with a relatively slow increase in salinity, the presence of disseminated salt beneath the Napoleon sandstone, the great variations in thickness of Napoleon sandstone within relatively short distances, and the presence of cross-bedding.¹¹

These conditions, it seems, may be best explained by supposing that the Michigan sea of Lower Marshall time, in which there was an abundance of life, was connected with the main sea by a narrow strait¹² across which was a submerged bar; and that at the beginning of Upper Marshall time this outlet was closed either by a diastrophic movement or by increasing conditions of aridity, bringing the bar above the surface of the water. The southern peninsula of Michigan would then represent an isolated basin in which evaporation would proceed rapidly, especially if the separation had been produced through an increasing aridity. The streams flowing into the basin would be of the torrential type characteristic of arid regions, and enormous delta deposits (encroaching upon the saline sink with increasing aridity) would produce cross-bedded deposits of sand of considerable thickness. If the rains were sufficiently frequent to prevent too rapid concentration of the waters of the saline lake, the clays which would be washed into the lake would be deposited with the salts which were being thrown down through the evaporation of the saline waters.

It is possible that in the closing stages of the Napoleon, drifting sands may have played an important part, advancing upon the waters and entrapping them, thus preventing the formation of concentrated salt deposits and making it possible that a portion of the Napoleon brine is the original sea water within which the deposition of the sandstone occurred.

¹¹ Winchell, A., Proc. Am. Phil. Soc. Vol. II, 1871, p. 74.

¹² Schuchert, Chas., Bull. Geol. Soc. Am., Vol. 20, Plate 80.

THE BEREA GRIT.

Although the Berea brines are no longer employed as a source of salt, they are of considerable interest on account of their earlier use at plants along the shore of Lake Huron.

Areal distribution. According to Lane,¹⁴ the Berea grit has not been observed in outcrops in Michigan, but may be traced in wells along the

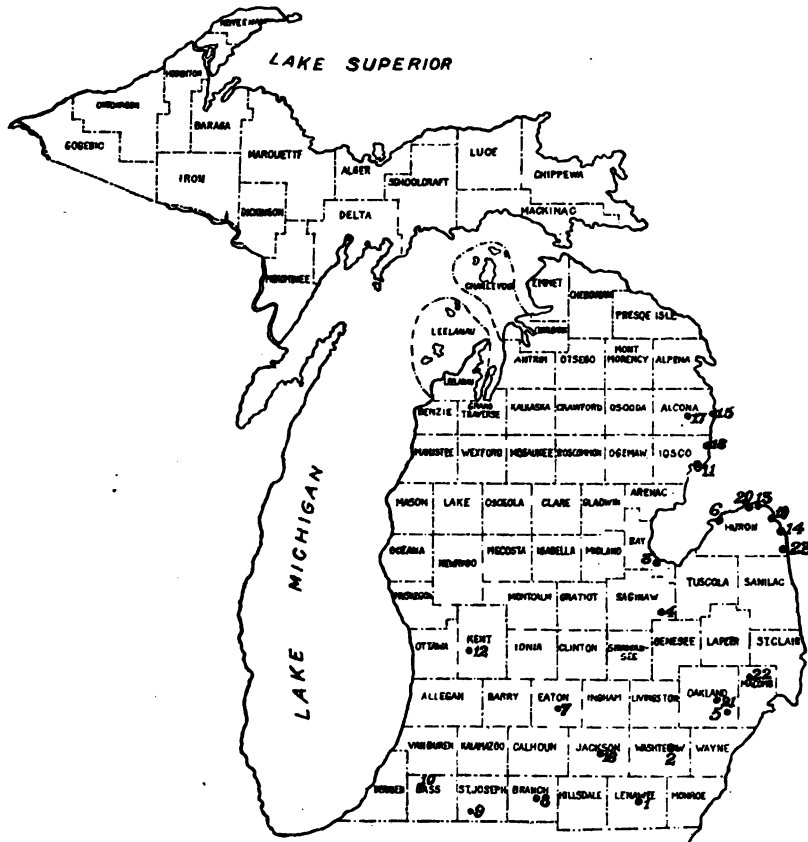


Figure 15. Showing the location of wells given in Table XII.

- | | | | | |
|----------------|-----------------|----------------------|------------------|-----------------|
| 1. Adrian. | 6. Caseville. | 11. East Tawas. | 16. Jackson. | 21. Pontiac. |
| 2. Ann Arbor. | 7. Charlotte. | 12. Gr'd Rapids. | 17. Killmaster. | 22. Romeo. |
| 3. Bay City. | 8. Coldwater. | 13. Grindstone City. | 18. Oscoda. | 23. White Rock. |
| 4. Blackmar. | 9. Constantine. | 14. Harbor Beach. | 19. Port Hope. | |
| 5. Birmingham. | 10. Dowagiac. | 15. Harrisville. | 20. Port Austin. | |

border of the Cincinnati anticlinal northeast from Adrian, past Ann Arbor, Birmingham, and Utica to the southeast corner of Sanilac county. From here, it is observed in the wells along the lake shore at White Rock, Harbor Beach, East Tawas, Oscoda and Harrisville, where it is found immediately underlying the drift. To the west it thins rapidly and occurs only in isolated patches.

¹⁴ Lane, A. C., Geol. Sur. Mich., Ann. Rpt., 1908, p. 73.

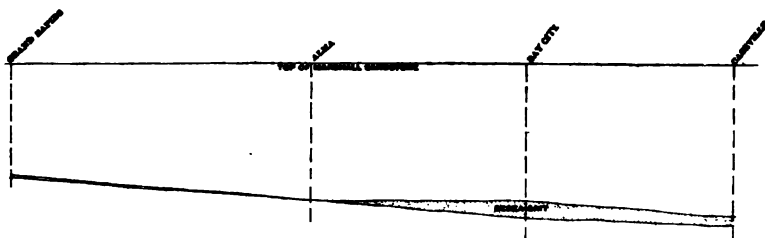


Figure 16. Structure section showing the Berea (after Lane).

Structure. While the Berea dips in general to the west and is therefore found at an increasing depth toward the center of the basin, as is shown in Table XII, from Fig. 16, we see that with respect to the Marshall, taken as a datum plane the dip is to the east and the resulting westward dip would therefore be less than that of the Marshall. The figure also shows that the deposit thins rapidly to the west and more gradually to the east. From the table it is likewise apparent that there is a decided dip north and south from White Rock and Harrisville respectively. Lane²⁸ inclines to the idea that the Berea grit was formed in a sea whose west shore ran nearly north and south through the center of Michigan.

Superjacent and subjacent strata. Above the Berea grit are a series of shales known as the Coldwater. The lowest member of the series is a black shale probably the equivalent of the Sunbury or Berea black shale of Ohio. This shale is characteristically present when the Berea grit appears below and often extends beyond the limits of the Berea. The Coldwater shales contain numerous sand streaks, many of which are brine bearing. These minor brine bearing strata are generally thin and vary so in position that correlation, at present, is not possible. Neither are any analyses of these brines available.

The underlying formation, the Antrim, consists of another series of shales. These shales are black in the lower portions, generally grading upward into blue shales with red shales, sometimes sandy, at the top. Lane²⁷ states that where the Berea grit is well marked the red phase has never been found.

Lithological character. The Berea is a micaceous sandstone, gray in color. It varies considerably in texture, being in general finer grained in the thicker portions. At some places, as at Oscoda, it is so fine grained and well cemented that it does not readily yield up its brines.

Berea brines. The Berea brines are very highly saturated and in general are characterized by a very low percentage of sulphates. Lane²⁸

²⁸Loc. cit.

²⁷Lane, A. C., Geol. Sur. Mich., Ann. Rpt., 1908, p. 75.

²⁸Loc. cit., p. 76.

TABLE XII.

Locality.	Approx. alt.	Total depth of well.	Depth to Beres.	Thickness of Beres.	Approx. alt. of top of Beres.	Remarks.
Adrian.....	810	1650	554	30	256	.....
Ann Arbor.....	875	1326	400	115	475	.....
Bay City.....	592	2865	2141	165	1540	.....
Bay City.....	585	3508	2100	170	1515	North American Chemical Co.
Beaumont.....	813	1677	1655	110	-1042	.....
Bloomington.....	.....	2300	1700	100	.....	.....
Cassville.....	906	2209	1680	40	-754	Gritty shale
Charlotte.....	983	1200	816	14	+167	Red calcareous shale.
Coldwater.....	803	1080	286	15	+517	Red shale
Constantine.....	580	883	678	195	-88	Grant and Sons
East Tawas.....	805	1775	11757	307	-570	Brine 26° Small amount.
Grand Rapids.....	592	2220	1010	70	-418	.....
Grindstone City.....	800	1920	603	61	-3	(Sand Beach)
Harbor Beach.....	640	506	230	30	+410	Beneath drift.
Hartsville.....	928	2455	1410	55	-482	.....
Jackson.....	870	1732	570	40	+100	.....
Kilmarster.....	590	1800 ±	950 ±	.....	-360	.....
Oscoda.....	600	787	716	71	-116	.....
Port Hope.....	934	1505	620	179	+314	Pack Wood & Co.
Pontiac.....	597	1225	1160	65	-563	.....
Port Austin.....	.....	1600	750 ±	.....	.....	.....
Romeo.....	590	1311	495	60	+95	.....
White Rock.....	.....	.....	.....	.....	.....	.....

For location of the wells see Fig. 15.

states that this may possibly be due to a reduction of the sulphates by the black shales, or the oil and gas sometimes associated with them, but that more probably they were originally low in sulphates. That the resulting hydrogen sulphide is not present in the brine is explained as being due to the presence of iron which has precipitated it as pyrite. With an increase in depth, the brines are marked by a considerable percentage of bromides and the bittern was formerly used at East Tawas for the manufacture of bromine. The following analyses bring out the composition and variations in the brines.

TABLE XIII.

	43.	44.	45.	46.	47.	48.
Sodium chloride.....	156.141	179.3	176.161	225.673	189.134	186.19
Magnesium chloride...	12.433	19.2	15.675	1.591	4.106	33.47
Calcium chloride.....	34.843	42.1	31.274	33.000	5.373	110.60
Calcium sulphate.....	0.350	trace	0.129	2.539	2.623	0.33
Ferric oxide and alumina.....						1.14
Total.....	203.767	240.7	223.239	232.803	201.236	331.73

43. Grant and Co., East Tawas, Mich. Depth of well, 905 feet. Salinometer 85°. C. A. Goessmann, analyst. Geol. Sur. Mich., Vol. III, p. 184.

44. Smith Kelly and Dwight, Oscoda, Mich. Depth of well, 1070 feet. Specific gravity, 1.182. Dr. H. C. Hahn, analyst. Ibid, p. 186.

45. Ayre's well, Port Austin, Mich. Depth of well, 1,198 feet. Salinometer 88°. Ibid, p. 183.

46. Harbor Beach, Mich. Depth of well, 702 feet. Salinometer 84°. S. P. Duffield, analyst. Geol. Sur. Mich., Vol. VII, Part II, p. 135.

47. Thomson Bros., White Rock, Mich. Depth of well, 566 feet. Geol. Sur. Mich., Vol. III, p. 184.

48. North American Chemical Co., Bay City, Mich. Depth to the Berea, 2,100 feet. Geol. Sur. Mich., Ann. Rpt., 1905, p. 388.

From the above analyses it will be seen that in general, there is a decrease in calcium sulphate with an increase in the depth to the Berea. Also we note that the percentage of earthy chlorides relatively to the sodium chloride increases rapidly in the same direction. (Compare analyses 47 and 48).

Origin of the Berea brines. As far as is known definitely³³ no deposits of rock salt exist within the Berea or within the overlying or underlying

³³Both Lane (Geol. Sur. Mich., 1908, p. 74) and Cooper (Geol. Sur. Mich., 1905, p. 158) seem to question the bed of rock salt reported as occurring in the Antrim in the Bay City well.

Coldwater and Antrim shales. Both of these formations, however, do contain alkali salts in fairly large proportions, as may be seen from the following analyses.

Coldwater shales.⁴⁰

Silica.....	58.70
Alumina.....	18.31
Ferric oxide.....	7.19
Calcium carbonate.....	1.80
Magnesium (carbonate?).....	.90
Alkalis.....	3.67
Water and organic matter.....	9.35

Total..... 100.00

Antrim Shales.⁴¹

Silica.....	55.95
Alumina.....	17.43
Ferric oxide.....	7.67
Calcium carbonate.....	2.14
Magnesium carbonate.....	1.55
Alkalis as K ₂ O.....	2.86
Water and organic matter.....	12.40

Total..... 100.00

Antrim Shale.⁴²

Volatile matter.....	17.96
Fixed carbon.....	6.49
Ash.....	77.55

Total..... 100.00

Ash.

Silica.....	70.54
Alumina.....	15.33
Ferric oxide.....	5.31
Lime.....	2.38
Magnesia.....	1.78
Alkalis by difference.....	5.56

Total..... 100.00

Also both shales show a considerable amount of water soluble constituents. Thus Ries⁴³ reports soluble salts in the Coldwater shales at Union City, 0.4%, at Quincy, 0.2%, and at Bronson, 0.5%; and in the Antrim shales at East Jordan, 0.8%, and at Norwood, 0.6%. It should be borne in mind that these determinations were made on samples obtained from outcrops, which would have been subjected to the greatest leaching action and therefore would probably have a smaller content of soluble salts than the same shale at greater depths.

It is possible that the brines of the Berea may have been formed through solution in either or both of these shale series. As we have seen, the Berea apparently forms a wedge, or possibly a lens, between the Coldwater and Antrim shales, thinning rapidly to the west and more gradually to the east. These shale layers would form relatively impervious strata which would tend to confine the movement of underground water to a direction parallel to their bedding. Water therefore

⁴⁰From White Rock. Cited by H. Ries, Geol. Sur. Mich., Vol. VIII, Part I, p. 44.

⁴¹Ibid, p. 46. A. N. Clark, analyst.

⁴²Ibid, p. 47. W. H. Johnson, analyst.

⁴³Ries, H., Geol. Sur. Mich., Vol. VIII, Part I, pp. 41-46.

which enters at the outcrops of the shale would pass downward along the bedding planes, dissolving the soluble salts en route, and finally enter the Berea which would act as a reservoir. That the brines of the Berea are under considerable hydrostatic pressure is shown by the fact that when pierced by wells the brine rises nearly to the top of the wells.

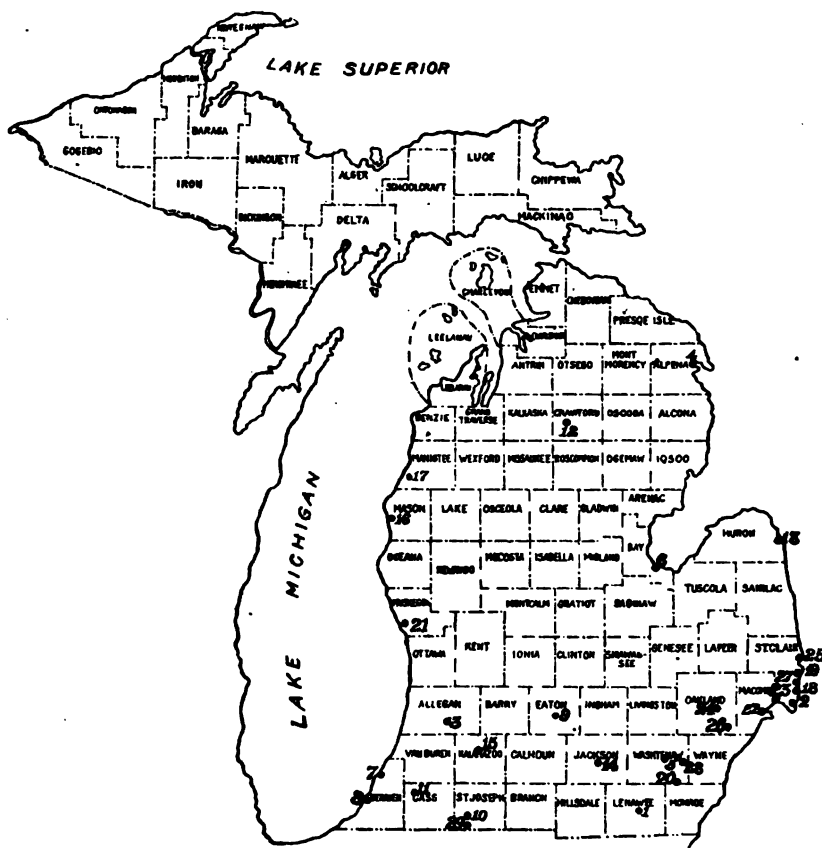


Figure 17. Showing location of wells in the Dundee.

- | | | | | |
|---------------|-------------------|-------------------|--------------------|-------------------|
| 1. Adrian. | 7. Benton Harbor. | 13. Harbor Beach. | 19. Marysville. | 25. Port Huron. |
| 2. Algonac. | 8. Bridgman. | 14. Jackson. | 20. Milan. | 26. Royal Oak. |
| 3. Allegan. | 9. Charlotte. | 15. Kalamazoo. | 21. Muskegon. | 27. St. Clair. |
| 4. Alpena. | 10. Constantine. | 16. Ludington. | 22. Mt. Clemens. | 28. Ypsilanti. |
| 5. Ann Arbor. | 11. Dowagiac. | 17. Manistee. | 23. New Baltimore. | 29. White Pigeon. |
| 6. Bay City. | 12. Grayling. | 18. Marine City. | 24. Pontiac. | |

In discussing the Antrim shale, it was stated that they generally change from a bituminous black shale through blue to red at the top, except where overlain by the Berea. This may represent an elevation of the land, perhaps with an eastward tilt, which per-

mitted the oxidation of the clay by the atmosphere; or it may mean increasing aridity. Lane⁴⁶ inclines to the former view. In either instance the Berea would represent a very much contracted sea in which the concentration of the saline constituents would probably be relatively high, and it is therefore conceivable that the Berea brine may be, in part at least, the original sea water in which the Berea was deposited.

Lane⁴⁶ suggests that the saltiness of the Berea brines may be due in part to the erosion of the underlying salt beds of the Salina during uplift. I have been unable however to find any record of the Berea or overlying formations coming into contact with the Salina in this region, and this suggestion can therefore be considered only as a possibility, which from our present knowledge we can neither prove nor disprove.

THE DUNDEE.

Areal distribution. The Dundee outcrops beneath the drift in the southeastern part of the state, in Monroe, Lenawee, and Wayne counties, along the shore of Lake Huron in southeastern Presque Isle county, and in a narrow zone running a little north of west from Cheboygan, in Cheboygan and Emmet counties, as shown in Fig. 10. From the records of wells, it is believed to extend over the entire southern peninsula of Michigan.

Structure. As indicated in Table XIV⁴⁷ the Dundee beds dip in general toward the center of the basin. There seems also to be a thickening of the beds in the same direction.

Superjacent and Subjacent strata. Above the Dundee is the Traverse group. This group consists of a series of limestones and shales, the lower member of which is the Bell shale, which is blue to black in color. The lithological change from the Bell shale to the Dundee limestone is of such a definite character that it may be quite easily recognized.

The Dundee is bounded below by a pronounced unconformity, as is shown by the fact that it rests upon the upturned and eroded edges of the Monroe series.⁴⁷ The lithological change from the Dundee to the Monroe, while generally one from limestone to dolomite, may therefore, be from limestone to sandstone, limestone to limestone, or limestone to shale. In addition to their general dolomitic character, the Monroe series is marked to a certain extent by the presence of gypsum or anhydrite.

⁴⁶Loc. cit., p. 76.

⁴⁷Loc. cit., p. 75.

⁴⁸For the location of the wells, see Fig. 17.

⁴⁹Grabau, A. W. and Sherzer, W. H., The Monroe Formation, Mich. Geol. and Biol. Sur. Pub. 2, Geol. Ser. 1, p. 54.

TABLE XIV.
Wells in the Dundee.

Locality.	Approx. alt.	Total depth of well.	Depth to Dundee.	Thickness of Dundee.	Approx. alt. of top of Dundee.	Remarks.
Adrian.....	810	1650	900		-90	Brine at 1035.
Algonac.....	590	1727	510		+80	
Algonac.....	600	1614	549		+51	Trace of mineral water.
Allegan.....	708	1400	1260		-532	
Alpena.....	609	1025	480		+129	
Ann Arbor.....	875	1326	930	120	-55	Brine containing 13% salts.
Assyria.....	917	2008 +	1875			
Bay City.....	585	3508	3270	235	-2685	North American Chemical Co.
Benton Harbor.....	600	1205	665	140±	-65	25 ft. salt sand at 513
Bridgman.....	636	1768	508	255	+128	Brine 97° Sp. gr. 1.198 at 2050.
Charlotte.....	906	2209	1983	226	-979	Brine with H ₂ S at 700.
Constantine.....	803	1080	90±		+13	Brine 60° salt by salinometer.
Courtwright, Ont.	830	1650	840		-210	Brine 100° salinometer at 874.
Dowagiac.....	760	2750	875	125	-115	Brine Sp. gr. 1.138 at 2750.
Grayling.....	1440	2750	2925?			Brine high in K ₂ O.
Harbor Beach.....	608	2555	1725	185?	-832	Brine at 1766.
Jackson.....	978	2555	1725	235±	-493	Strong brine.
Kalamazoo.....	777	2038	1622	135	-25	Brine at 750.
Kalamazoo.....	590±	2038	622	135	-25	
Narine City.....	600	1050	558	157	+42	
Marysville.....	870	1443	298	107	+572	
Millan.....	594	2627	2000±	50±	-407	Brine 100° sal.
Monroe.....	617	1040	400	210	+217	
Nt. Clemens.....		1640	690	130		
New Baltimore.....	934	1805	1115		-181	Very strong brine.
Pontiac.....	600	1720	710	120	-110	Porous lime salt brine.
Port Lambton, Ont.		2205	520			Salt sand at 548, 553, 536.
Roseland.....		1210	520	180		Mineral water at 525, 530, and 570.
Ypsilanti.....		763	683	80	+117	Salt sand at 710.
White Pigeon.....	500					

Lithological character. The Dundee is generally a very pure limestone. Lane⁴⁸ states that it frequently runs over 98% calcium carbonate. It is gray, yellowish, or buff in color, and in places especially near the top of the formation, is cherty or sandy in character. This cherty phase is rather porous and acts as a repository for the brines.

Dundee brines. The Dundee is not always brine-bearing and its brines vary considerably in composition. Where present, the brine is generally very strong, but the high percentage of earthy bases renders it economically unfitted for the manufacture of salt where so many purer brines are obtainable. It is of considerable importance, however, in that it is used in the preparation of medicinal salts. Its composition may be seen from the following analyses.

TABLE XV.

	49.	50.	51.	52.	53.
Sodium chloride.....	66.6832	119.66	26.197644	134.684	0.409
Potassium chloride.....	2.8181			0.873	trace
Ammonium chloride.....	0.1431			3.07	
Calcium chloride.....	5.2492	78.02	2.45765		
Magnesium chloride.....	6.7846	24.67	2.19596	20.128	
Magnesium bromide.....	0.0488	1.27	0.188	2.116	
Magnesium sulphate.....			1.774		1.100
Magnesium iodide.....	0.0003				
Magnesium carbonate.....					0.090
Calcium bicarbonate.....	1.7600		a0.98181		
Calcium sulphate.....	3.7721		3.01121		1.220
Ferrous bicarbonate.....	0.0140		trace		c0.018
Potassium sulphate.....			0.6058	0.248	
Sodium hyposulphite.....	0.0177				
Sodium hydrosulphite.....	0.0136				
Sodium sulphide.....			0.1445		0.580
Alumina.....	0.0033				
Silica.....	0.0085		0.3398		0.017
Hydrogen sulphide.....	0.3146		b32.216	absent	b44.5
Carbonic acid gas.....	0.7147				
Total.....	88.346	237.62	38.6788	233.746	3.44

a. Normal carbonate. b. In cubic inches per gallon. c. As Fe_2O_3 .

49. Deep-spring Mineral Water, Port Huron, Mich. Depth of well, 750 feet. Above analysis compiled from analyses by Dr. E. Ristenpart, Patterson, N. J., and Professor F. S. Kedzie, Mich. Agr. Coll. (Mich. Geol. Sur., Ann. Rpt., 1903, p. 109.)

50. Assyria, Mich. Analysis by E. E. Ware, University of Michigan, Ann Arbor, Mich. The spectroscope revealed strontium, lithium, and perhaps barium. (Geol. Sur. Mich., Ann. Rpt., 1903, pp. 277-278).

51. Ypsilanti Mineral Bath Co., Ypsilanti, Mich., Moorman well. Water drawn September 5, 1884, at which time the well was cased to 550 feet to shut off all waters above the Dundee. Specific gravity,

⁴⁸Lane, A. C., Ann. Rpt. for 1908, p. 70.

1.0280. Reaction, alkaline. Jas. H. Shepard, analyst. (U. S. G. S. Water Supply Paper No. 31, pp. 73 and 76.)

52. Salling Hanson and Co., Grayling, Mich. Depth of well, 2,750 feet. Analysis from the U. S. G. S. Mineral Resources, 1908, Part 2, p. 656. This brine may come from the lower portion of the Traverse, but is probably from the Dundee.

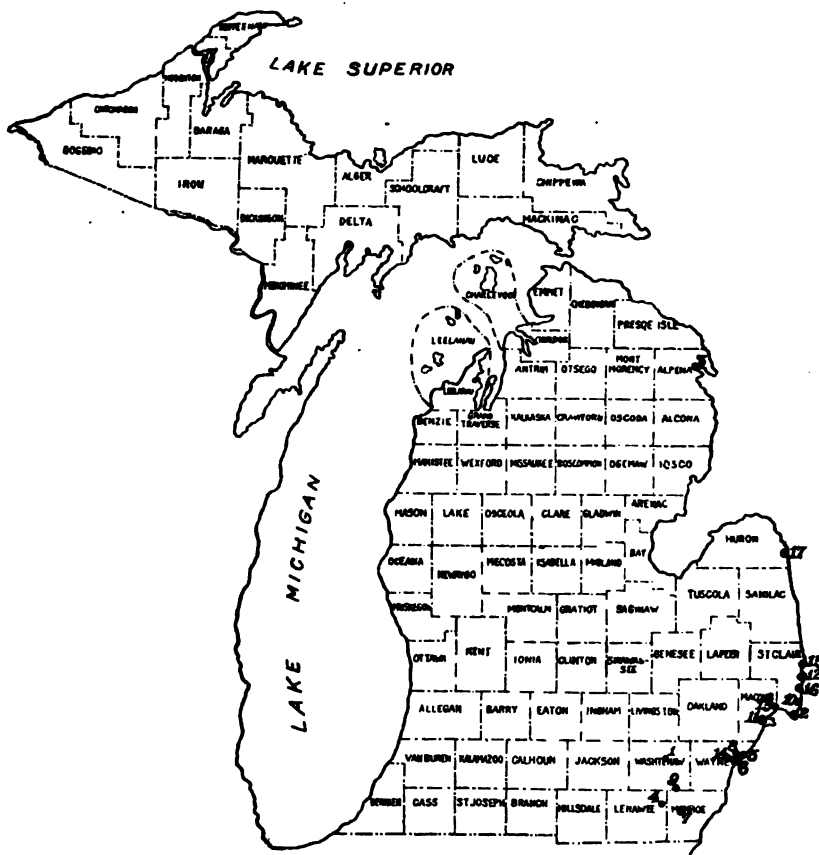


Figure 18. Showing the location of wells in the Monroe formation.

- | | | | |
|---------------|---------------|------------------|-----------------------------------|
| 1. Ann Arbor. | 5. Detroit. | 9. Milan. | 13. New Baltimore. |
| 2. Algonac. | 6. Delray. | 10. Marine City. | 14. Oakwood. |
| 3. Alpena. | 7. Dundee. | 11. Mt. Clemens. | 15. Port Huron. |
| 4. Britton. | 8. Ford City. | 12. Marysville. | 16. St. Clair. |
| | | | 17. Sand Beach
(Harbor Beach). |

53. Butler's well, Frankfort, Mich. Main flow at 1,400 feet. R. C. Kedzie, analyst. (U. S. G. S. Water Supply Paper No. 31, pp. 72-3.)

The following analyses of brine from the Ryerson well, Muskegon, Michigan, are especially interesting on account of the large percentage of potassium which is shown. Depth of well, 2,050 feet.

	54.	55.
Calcium chloride.....	58.205	54.10
Calcium sulphate.....	0.548	4.22
Magnesium chloride.....	17.034	14.97
Magnesium bromide.....	2.346	2.37
Potassium chloride.....		22.16
Sodium chloride.....	174.933	157.17
Total.....	233.103	255.95
Specific gravity.....	1.20342	1.21

54. Analysis by Professor A. B. Prescott, University of Michigan, September 8, 1883. Geol. Sur. Mich., Ann. Rpt., 1901, p. 233. Lane states that the potassium chloride is probably included in the sodium chloride.

55. Analysis by C. A. Goessman, September 25, 1883.

As will be noted from the foregoing analyses the most prominent characteristic of the Dundee brines is their high content of hydrogen sulphide. Furthermore the percentage of earthy bases is high relatively to the alkalis, as are also the chlorides relatively to the sulphates.

Origin of the Dundee brines. Inasmuch as the origin of the Dundee brines seems to be related to that of the Monroe brines, it will be discussed under the Monroe formation.

UPPER MONROE OR DETROIT RIVER SERIES.⁴⁹

Although but one attempt, namely that at Mt. Clemens, has ever been made to manufacture salt from the brines of this series, the brines are of considerable importance on account of their medicinal properties. The major portion of the mineral waters used at the health resorts of southeastern Michigan, especially at Mt. Clemens and along the St. Clair river, are derived from this horizon.

Areal distribution. The Upper Monroe seems to be confined areally to the eastern and southeastern part of the state, where it outcrops beneath the drift in a narrow belt extending from the southeast corner of Lenawee county northeast through Monroe county into Wayne county and across the Detroit river into Canada. It is also traceable in wells north from Detroit, appearing at Mt. Clemens, New Baltimore, Marine City, St. Clair, Port Huron, Harbor Beach, and Alpena.

Structure. According to Lane,⁵⁰ these beds seem to have been deposited in a narrow trough, the series not always being complete, on account of the lower beds having been overlapped by the upper mem-

⁴⁹For a more complete discussion, see Mich. Geol. and Biol. Sur., Pub. 2, Geol. Ser. 1, The Monroe Formation, Grabau and Sherzer, 1909.

⁵⁰Lane, A. C., Geol. Sur. Mich., Ann. Rpt., 1908, p. 67.

TABLE XVI.

Locality.	Approx. alt.	Total depth of well.	Depth to Upper Monroe.	Thickness of formation.	Approx. alt. of top of Monroe.	Remarks.
Ann Arbor.....	875	1326	1045	200	-170	Ann. Rpt. 1901, p. 215.
Algonac.....	590?	1727	700?	.....	.....	Albert Miller well.
Alpena.....	609	1025	600	.....	.....	Near bed of Thunder Bay river.
Britton.....	703	1700	500	250	+205	.....
Court right, Ont.....	588	1665	629	370	-104	.....
Detroit.....	610	2097	8	.....	.....	Stroh's well.
Delray.....	575	.....	135	230	+440	.....
Dundee.....	675	2197	103	132	+572	.....
Ford City.....	580	1603	80+	270+	+506	.....
Marine City.....	685	1843	425	110	+263	.....
Marine City.....	600	1641	770	290	-170	Lester & Roberts.
Marine City.....	600	1630	750	250	-150	National Salt Co. Brine at 750.
Marine City.....	600	1470	825	265	-225	Morley well, 1 mile north of city.
Mt. Clemens.....	617	1060	610	375	+7	Mr. Coursin, owner.
Marysville.....	600	1150	745	265	-145	Burch farm, strong salt water at 745.
New Baltimore.....	.....	1640	820	b	.....	Mineral water at 815, 970, and 985. H ₂ S strong at 985.
Oakwood.....	575	1660	145	265	+430	Detroit Salt Shaft well.
Port Huron.....	611	1685	685	480	-74	Plate LVII, G. S. M. Vol. V.
St. Clair.....	.....	1850	910	270±	.....	Diamond Crystal Salt Co.
Sand Beach (Harbor Beach).....	.....	1920	1844?	.....	.....	Sand Beach Mineral Bath Co.

a. Dundee limestone with sulphur water in the Monroe beds 300-615 feet. Geol. Sur. Mich., Ann. Rpt., 1901, p. 217.
b. Lower limit not determinable from the data at hand on account of the absence of the Sylvania sandstone.

bers.⁴¹ After the deposition of the Upper Monroe and before the deposition of the Dundee, a deformation of the Monroe beds occurred which in southeastern Michigan resulted in the production of at least one anticline with two synclines.⁴² The trend of the axes of the folds is about N. 60° E. The axis of the anticline passes through Wyandotte and about five miles north of Woolmuth quarry. Another incomplete anticline passes south of Anderdon quarry and near Scofield. The thickness of the formation and depths at which it is found are shown in Table XVI.⁴³

Superjacent and subjacent strata. The Upper Monroe is overlain unconformably by the Dundee formation, as indicated under the discussion of the latter. Its lower limits, where determinable, are marked by the appearance of the Sylvania sandstone. This sandstone, which is believed by Grabau and Sherzer⁴⁴ to be of subaerial origin, is characterized by the whiteness of the quartz grains and the imperfection of cementation. It is generally present in the wells of sufficient depth in southeastern Michigan, but is absent⁴⁵ at New Baltimore, and replaced by siliceous dolomite at Mt. Clemens, and in the vicinity of St. Clair.

Lithological character. The complete series of the Upper Monroe consists of four beds, three of which are dolomites and one, a limestone. The dolomites tend to be brown in color and the portion just above the Sylvania is generally very siliceous. In some instances, the various members show quite a high content of fossils.

Upper Monroe brines. The nature of the Upper Monroe brines may be seen from the analyses given in Table XVII. It is to be noted that these brines are generally relatively high in earthy bases and in their content of hydrogen sulphide. In this respect they resemble quite closely the Dundee brines. In the analyses given there appears to be a considerable variation in the brines in wells quite close together or, even in different samples from the same well. This may be due to changes in the brine but is more likely due to differences in depths to which the wells are cased. Analyses 56 and 57 are of samples from wells relatively near to one another, yet in 56 bromine and potassium chloride do not appear, whereas in 57 they are present in very considerable amounts. This might be due to different methods of analysis, but inasmuch as both were examined by the same analyst, it does not seem likely. Furthermore it is to be noted that the calcium chloride and potassium bear a sort of reciprocal relationship to each other. According to Lane,⁴⁶ this reciprocal relationship is not at all uncommon.

⁴¹Grabau, A. W. and Sherzer, W. H., loc. cit., p. 41.

⁴²Ibid, p. 57.

⁴³For location of the wells, see Fig. 18.

⁴⁴Loc. cit.

⁴⁵Grabau and Sherzer, loc. cit., p. 70.

⁴⁶Lane, A. C., U. S. G. S. Water Supply Paper No. 31, p. 79.

TABLE XVII.

	56.	57.	58.	59.	60.	61.	62.
Ammonium chloride.....			trace	d 934.5			
Calcium chloride.....	105.46	40.054	b 172.41	e 13.35	42.820	56.89	62.6636
Calcium sulphate.....	2.06	1.254	b 35.20	e 100.335	11.060	0.90	0.9936
Calcium carbonate.....	trace		b 3.98	d 0.98			
Magnesium chloride.....	14.46	3.470	b 129.60	e 648.45	18.596	4.85	5.3542
Magnesium bromide.....		0.980		d 9.246		22.50	24.84
Magnesium iodide.....	trace		bc 0.32	e 0.091			
Magnesium carbonate.....	trace		trace	d 0.70			
Sodium chloride.....	116.00	128.342	b 8637.44	e 11900.00	86.080	162.64	179.2391
Sodium sulphate.....		0.170	b 77.25	e 170.00	0.028		
Potassium chloride.....		24.00			11.602	34.22	24.84
Alumina.....	12.00			d 29.47	0.044		
Silica.....	5.80	1.700	b 8.97	e 27.421			0.7303
Ferric oxide.....		0.430		d 0.504			
				e 0.360			
				fe 0.080	g 0.029		
Total solids.....	255.78	200.4400	b 9065.17	d 13654.105	170.259	282.00	311.60
				e 195.062			
Hydrogen sulphide.....	a 25.597		a 27.152	a 40.00	a 9.910	a 10.5	a 10.745
Carbon dioxide.....			trace	a 5.85	a 3.457		

a. Cubic inches. b. Grains per gallon. c. Iodine. d. Grains per U. S. gallon. e. Grams per kilogram. f. Ferrous carbonate. g. $\text{FeH}_2(\text{CO}_3)^+$.

The most likely explanation seems to be that in the Oakland well, which was cased to 1000 feet, waters which were allowed to mix with the deeper brines in the Somerville well were excluded. Analyses 58 and 59 are of samples from the same well. The first analysis probably represents the original brine before the casing was withdrawn, the second, after the waters from higher horizons had been allowed to intermingle. The variations especially in bromine and potassium chloride between 59 and 60, which is from the same locality as 59, may be due to the fact that 60 is shallower and therefore has not been contaminated with lower waters high in sodium chloride. If this be true, it would perhaps help to support Lane's hypothesis that the decrease in the bromine and potash content of the Harbor Beach well (61 and 62) as shown by later analysis, is due to the intermingling of the deeper waters with those at 1860 feet, the point at which the samples whose analyses are represented by 61 and 62 were taken.

56. Oakland Hotel well, St. Clair, Mich. Depth of well, 1,250 feet, cased 1,000 feet. S. P. Duffield, analyst. U. S. G. S. Water Supply Paper No. 31, pp. 79 and 84.

57. Somerville Mineral Spring, St. Clair, Mich. S. P. Duffield, analyst. U. S. G. S. Water Supply Paper No. 31, pp. 79 and 84.

58. Original well, Mt. Clemens, Mich. H. F. Meier, analyst. U. S. G. S. Water Supply Paper No. 31, pp. 79 and 85.

59. Same. S. P. Duffield, analyst. Reference, same.

60. Clementine well, B. B. Coursin, proprietor, Mt. Clemens, Mich. Depth of well, 1,060 feet. Theo. Tonnele', McKeesport, Pa., analyst. U. S. G. S. Water Supply Paper No. 31, pp. 79-80 and 85.

61. Mineral well, Harbor Beach (Sand Beach), Mich. Depth of well, 1,920 feet. R. C. Kedzie, analyst, August 1890. Geol. Sur. Mich., Vol. V, Part II, p. 82. Results changed to grams per kilogram.

62. Same. S. P. Duffield, analyst. Geol. Sur. Mich., Vol. V, Part II, p. 82.

Origin of the Dundee and Monroe brines. While it is difficult to determine the exact nature of the Dundee brines, as is also the case with those of the Monroe, owing to the fact that the wells from which they are obtained are rarely cased to a sufficient depth to limit the brines to a definite horizon, thereby making correlation possible, we note that in general the brines of these formations are characterized, in addition to the hydrogen sulphide content, by a high percentage of earthy chlorides relatively to the sodium chloride, and in some instances, by a very noticeable percentage of potash. These brines, it will be noted, resemble very closely the mother liquors, or bitters, produced through the evaporation of the purer brines from which salt is manufactured. It would seem therefore that these brines must represent either natural

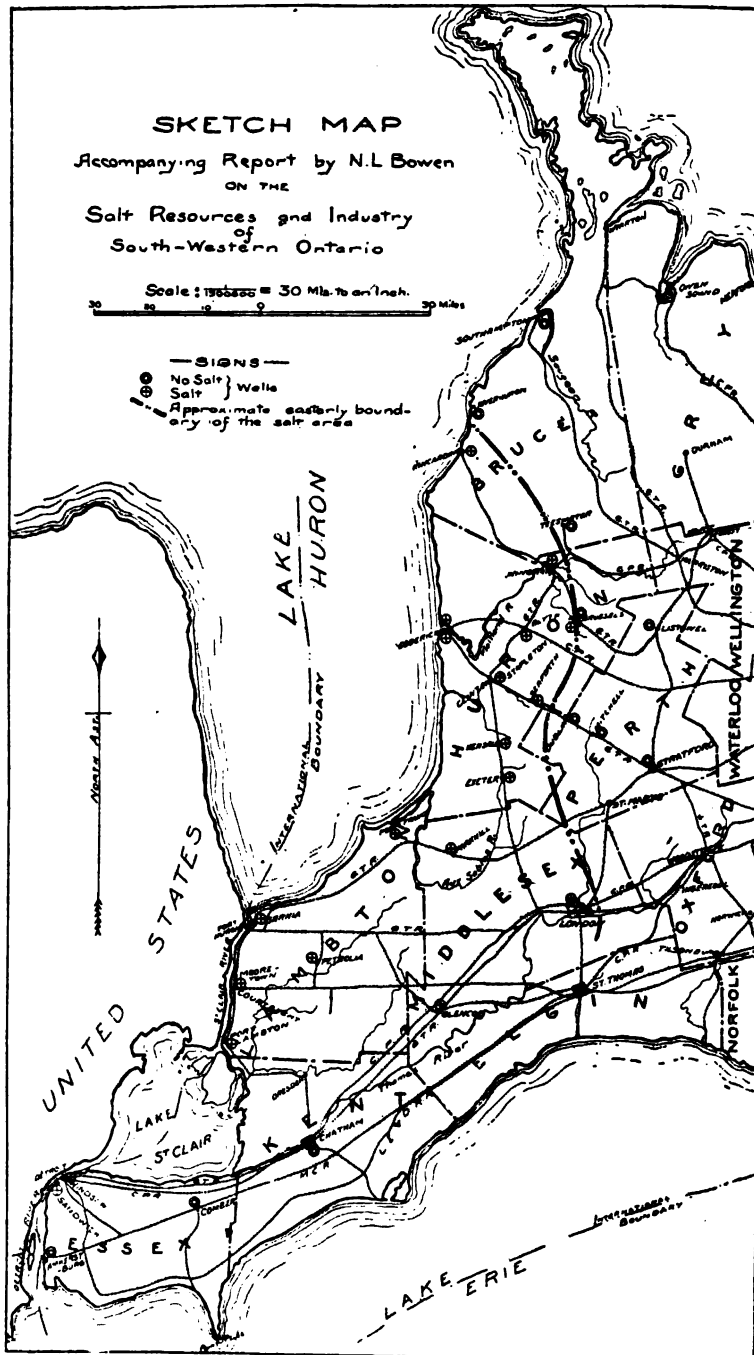


Figure 19. Map showing the eastern limits of the salt deposits in Canada (after Bowen). Canadian Bureau of Mines, 1911.

mother liquors, or they have been derived from deposits which have been formed through the evaporation of mother liquors.

If they represent the natural mother liquors, it is to be expected that deposits of the less soluble salts should be found in more or less close association with them. Within the Dundee no deposits either of rock salt or gypsum have been reported; we do find, however, in the Monroe formation anhydrite and gypsum. (It may be that some of the rock salt deposits are of Monroe age, but they are, on the basis of our present lack of knowledge, arbitrarily assigned to the Salina). According to Grabau and Sherzer,⁷ the Monroe formation is separated from the Dundee above and the Salina below by disconformities; the Monroe overlapping the Salina onto the Niagara, and the Dundee overlapping the various members of the Monroe formation.

There seems therefore to be two possibilities as far as the origin of the Monroe brines is concerned: (1) That the lake or lakes in which the rock salt of the Salina was deposited did not disappear entirely, and that the Monroe brines represent, in part at least, the mother liquors from the Salina, which have been retained within the interstices of the rock, or the contained salts which have been deposited around the grains of the rock; (2) that the Monroe brines were formed by the erosion of a portion of the Salina in which these salts had originally been deposited. Although difficult of proof, the latter possibility seems the more plausible. This point of view may perhaps be better understood after the discussion of the origin of the salt deposits of the Salina.

The Dundee brines may then possibly have been formed through the erosion of the Monroe formation and the solution of the soluble salts therein contained.

THE SALINA.

The separation of the Salina from the Lower Monroe is very difficult, especially where no rock salt is present. Therefore, in the present discussion we shall limit ourselves to those portions of the Salina in which rock salt is known to exist.

Areal distribution. In Michigan there are three districts in which rock salt has been found,—(1) along the Detroit and St. Clair rivers, (2) the Ludington-Manistee district, and (3) the Alpena district.

As far as our present knowledge goes, the district along the Detroit and St. Clair rivers is by far the largest of the three. The southern limit of the district has been pretty well established since in the six Church wells about one half mile north of Trenton salt was found in all but one. As may be seen from Tables XVIII and XIX, no salt

⁷Loc. cit.

was found at Monroe, Dundee, Britton, or Jackson, while there is but five feet at Milan. To the north Port Huron is the last point from which information is available. However, as the aggregate thickness of the salt beds at this point is about four hundred feet, it is reasonable to expect that they continue considerably farther north. Between these north and south limits, salt is found in a series of wells at Wyandotte, Ford City, Ecorse, River Rouge, Detroit, Pearl Beach, Algonac, Marine City, and St. Clair. To the west our information is again limited on account of the increased depth at which the formation occurs. At Romulus, we find beds of salt aggregating 329 feet in thickness and at Royal Oak, a total thickness of 609 feet. There is, therefore, every indication of a decided northwestward extension of the salt bearing strata. Eastward the salt extends into Canada and is found in wells at Petrolia and Goderich, but is absent at Stratford, Dublin, and Inverhuron. The eastern limits of the salt deposits as fixed by the Canadian Bureau of Mines⁵⁸ is shown in Fig. 19. If a physical connection exists between the Salina salt beds of Michigan and those of New York, it must be either as a narrow strait in the region of Amherstburg, Comber, and Chatham, where its apparent absence may be the result of an insufficient depth having been attained in the wells at those points, or, and this seems more likely, farther north across Lake Huron and Georgian Bay.

Manistee and Ludington would appear to occupy a position near the edge of the Salina, inasmuch as no salt was found at Muskegon, Milwaukee, and Frankfort in wells which should have pierced the beds had they been present. As to the eastward extension of the beds, no information is available.

The Alpena area has been explored the least of any of the three mentioned. An aggregate thickness of 311 feet of salt and anhydrite appears in the well of the Alpena Land Co.⁵⁹ at Grand Lake near Alpena, while more recent reports, the exact data for which are not at hand, give over 600 feet of solid rock salt. These facts would seem to indicate the existence of quite an extensive salt area.

In view of the fact that these deposits appear very closely related in age, and having regard to the general structure of the state, we are comparatively safe in assuming that these three districts are but parts of one large area and that at sufficient depth salt may reasonably be expected anywhere within lines joining them.

Structure. The variations in the thickness and number of the individual salt beds in the different areas make their correlation extremely difficult. Undoubtedly many of them are purely local, while variations in the contour of the floor upon which they were laid down, would re-

⁵⁸20th Report, Ontario Bureau of Mines, 1911, p. 256.

⁵⁹Geol. Sur. Mich., Ann. Rpt., 1908, p. 93.

sult in such changes in thickness as to render a layer unrecognizable at certain points. Lane⁶⁰ states that there is usually quite a gap with-

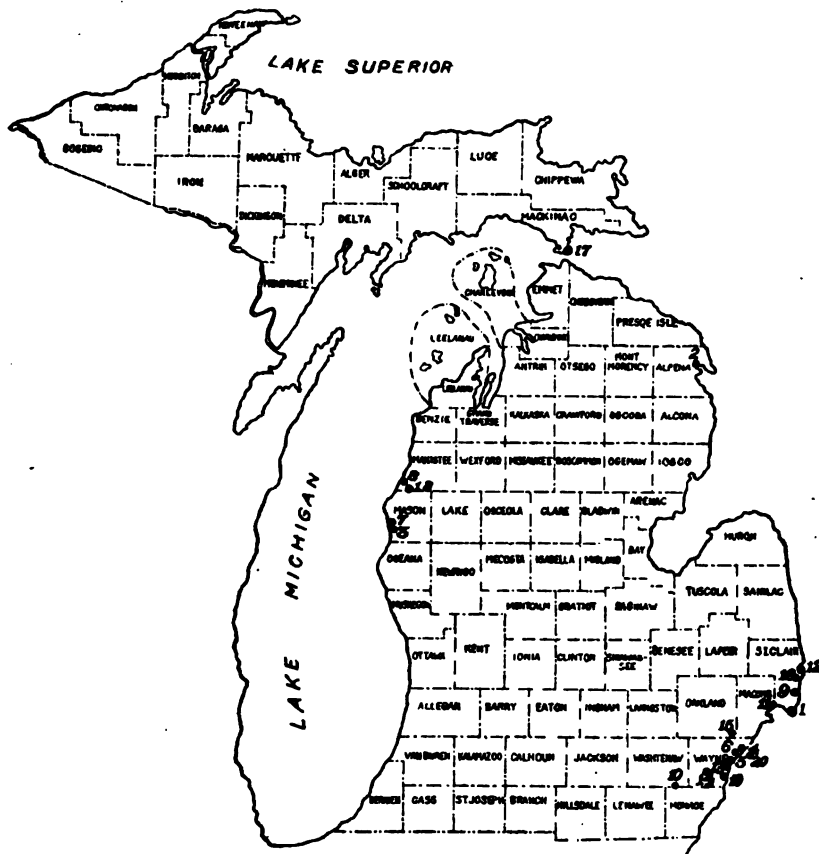


Figure 20. Showing the location of wells which encounter salt in the Salina.

- | | | | |
|------------------|-----------------|--------------------|-------------------|
| 1. Algonac. | 6. Ford City. | 11. New Baltimore. | 16. St. Clair. |
| 2. Alpena. | 7. Ludington. | 12. Port Huron. | 17. St. Ignace. |
| 3. Buttersville. | 8. Manistee. | 13. River Rouge. | 18. Strophach. |
| 4. Detroit. | 9. Marine City. | 14. Ronulus. | 19. Wyandotte. |
| 5. Ecorse. | 10. Milan. | 15. Royal Oak. | 20. Windsor, Ont. |

out salt above the lowest and largest bed. Owing to the fact that in the Diamond Crystal Salt Co's. No. 5 well at St. Clair no large gap appears above their largest bed, which has a thickness of over 250 feet, he believes that this is not the first salt bed, but the one above it, and may correspond to the bed found at Zug Island at 1290-1528, River Rouge Improvement Co. at 1180-1573, Solvay No. 17 at 1400-1599, Edison Fort Wayne well at 1445-1636 and possibly, Royal Oak at 2115-2475.

⁶⁰Lane, A. C., *ibid.*, p. 58.

The possibility of decided changes in short distances may be seen from a comparison of the Diamond Crystal wells Nos. 5, 6, and 7, which may be represented as occupying the apices of a triangle, whose sides are approximately 1000 feet in length. The well records from the lime layer above the uppermost salt bed are as follows:

	5.	6.	7.
Lime.....	1595-1630	1600-1620	.....
Salt.....	1630-1660	1620-1625	1623-1653
Lime.....	1660-1748	1625-1635	1653-1743
Salt.....		1635-1655	.....
Lime.....		1655-1750	.....
Salt.....	1748-1768	1750-1770	1743-1763
Lime.....	1768-1773	1770-1775	1763-1768
Salt.....	1773-1783	1775-1785	1768-1778
Shale.....	1783-1859	1785-1855	1778-1854
Salt.....	1859-1883	1855-1885	1854-1884
Lime.....	1883-1893	1885-1890	1884-1892
Salt.....	1893-1903	1890-1905	1892-1902
Lime.....	1903-1913	1905-1912	1902-1912
Salt.....	*1913-2165	†1912-2113	1912-2020
Lime.....			2020-2025
Salt.....			2025-2130
Lime.....			2130-2135
Salt.....			2135-2165
Lime.....	2165-2170		2165-2200

*Five feet of lime between 2100 and 2165.

†Stopped in salt.

Although the correlation of the different beds in various localities may be very difficult, if at all possible, yet from an examination of Table XVIII,⁴¹ we see that in general salt is struck at greater and greater depths away from the Cincinnati anticlinal, and also that the beds increase in thickness down the dip. How far this increase will proceed we have no means of knowing inasmuch as no records are available beyond Royal Oak. It should be borne in mind however that these remarks refer only to the region along the Detroit and St. Clair rivers. Our information from the other areas is too meager to permit of a determination of the structure, but it is probable that in both instances the beds dip toward the center of the basin.

⁴¹For the location of the wells, see Fig. 20.

TABLE XVIII.^a
Wells in the Salina showing salt.

Locality.	Approx. alt.	Total depth of well.	Approx. alt. of top of first salt.	Depth to first salt.	Number of salt beds.	Aggregate thickness of salt beds.	Remarks.
Algonac.	580	1727	-910	1500	3	183	80 feet of mixed salt and shale.
Algonac.	600	1614	-950	1550	1	52	Algonac Salt Co.
Alpena.	609	1025	-481	1000	1	311	Near bed of Thunder Bay river.
Alpena.		1712		1284	5		Streaked with anhydrite.
Buttersville.	590	2260	-1652	2242	1		
Detroit.	610	2097	-540	1150	3	339	Stroh's Brewery.
Ecorse.	575	1627	-235	800	7	449	Worcester Salt Co.
Ford City.		1300		830	5	237	Ford No. 1.
Ludington.	590	2304	-1706	2296	1	8	Stearns well.
Ludington.		2404 +		2263	4	44	Anchor Salt Co., No. 4.
Manistee.		2012		1978	2	31	Sands well.
Manistee.	610	2000		1980	1	20	Peters No. 6.
Marine City.	600	2016	-1375	1985	1	30	Puckley and Douglas.
Marine City.	600	1641	-1004	1604	1	33	Lester and Roberts.
Marine City.	600	1735	-1034	1634	1	101	Baird Bros. Still in salt.
Marine City.	600	1737	-1022	1622	3	100	Toledo Salt Co.
Marine City.	600		-965	1565	1	250	Davidson-Wonsey Co.
Marine City.	600	1630	-970	1570	2	160	Michigan Salt Co., No. 1.
Marine City.	600	1751	-970	1570	3	163	Michigan Salt Co., No. 2.
Millan.	870	1643	-670	1540	1	5	
New Baltimore.		1640		1600	1	40	
Petrolia, Ont.		377		1210	5	595	Carmen well.
Port Huron.	590	2185	-1075	1845	7	452	
River Rouge.		1603		915	10	378	S. E. & N. W. 1 Sec. 12.
Romulus Twp.	620	2820	-305	1523	9	329	
Royal Oak.		270		1538	7	909	Diamond Crystal, No. 5.
St. Clair.	590	2170	-1040	1630	7	346	Diamond Crystal, No. 6. Stopped in salt.
St. Clair.	590	2113	-1030	1620	1	306	Four feet shale and salt.
St. Ignace.	600	616	-1290	400	1	34	Stromach Lumber Co.
Stromach.	604	1972	-1329	1930	4	281	Stromach Salt Co.
Wyandotte.	580	1322	-319	799	1	34	Monon Salt Co.
Wyandotte.		1167	-517	1127	1	40	C. F. R. R., No. 11.

^aFor location of wells, see Fig. 20.

TABLE XIX.⁴³

Wells in the Salina horizon showing no salt.

Locality.	Approx. alt.	Depth of well.	Remarks.
Benton Harbor.....	600	1205	Salt water at 1000 feet.
Britton.....	705	1643	
Cheboygan.....		2750	61° brine at 1360 feet.
Dowagiac.....	760	1760	
Dundee.....	680	2133	N. E. ¼ N. E. ¼ Sec. 25, T. 6 S., R. 6 E.
Dundee.....	660	2150	N. W. ¼ N. W. ¼ Sec. 8, T. 6 S., R. 7 E.
Frankfort.....	600	1800 ±	
Goshen, Ind.....	789	2054	
Grand Rapids.....	605	2220	Brine at 2200.
Jackson.....	928	2455	Anhydrite and salty.
Kalamazoo.....	777	2250	From 1490 to 1650 salty with anhydrite.
Monroe.....		1765	
Muskegon.....	594	2627	
Niles.....	681	1140	
Port Rowan, Ont.....		1460	
Port Lambton, Ont.....		1720	
South Bend, Ind.....	725	1670	
Trenton.....		1370	Church well.

⁴³For location of wells, see Fig. 21.

1. Lane, A. C., Geol. Sur. Mich., Ann. Rpt., 1908, p. 58. According to Bowen, (20th Report. Ontario Bureau of Mines, 1911, p. 255.) however, salt occurs at Port Lambton.

Superjacent and subjacent strata. Above, the Salina passes imperceptibly into the Lower Monroe. The separation of the two is therefore very difficult, even if possible. Lane⁴⁴ finds that if we go 400 feet below the Sylvania sandstone, where this is present, and then take the top of the nearest salt or gypsum bed, fairly consistent results are obtained. The Lower Monroe is essentially a series of dolomites and shales containing beds of gypsum or anhydrite. The lower boundary of the Salina is somewhat better marked, since the uppermost member of the Niagara formation, the Guelph dolomite, is a characteristically hard and white dolomite.

Lithological character. The Salina in Michigan is in the main a limestone formation. The limestones, which are dolomitic, are generally gray, buff, or brown in color and at times argillaceous. In fact the appearance of shaley layers is not at all uncommon. Interbedded with the dolomitic limestones are bands of salt and anhydrite. The beds of salt vary from a fraction of a foot to several hundred feet in thickness. The anhydrite layers are relatively much thinner. Generally the salt rests upon the anhydrite, but in some instances it appears to rest directly upon the limestone or dolomite.

Salina brines. With the exception of the rock salt, which is obtained from the shaft of the Detroit Salt Co., Oakwood, the salt of the Salina formation is obtained in Michigan from wells in the form of an artificial

⁴⁴Lane, A. C., Geol. Sur. Mich., Ann. Rpt., 1908, p. 58.

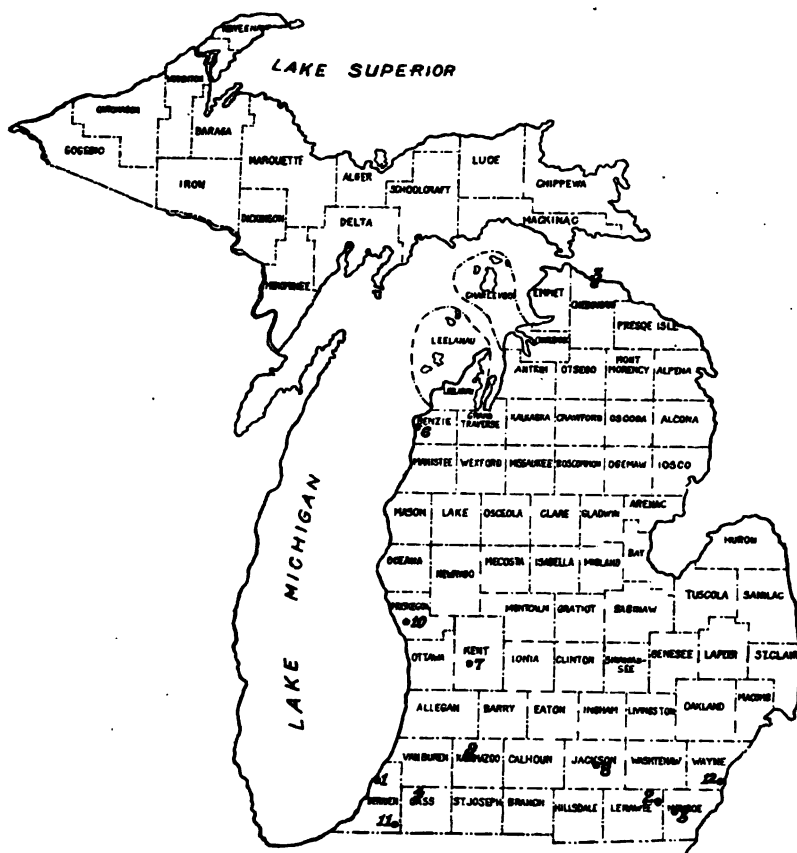


Figure 21. Showing location of wells which enter the Salina horizon but show no salt.

- | | | |
|-------------------|------------------|---------------|
| 1. Benton Harbor. | 5. Dundee. | 9. Kalamazoo. |
| 2. Britton. | 6. Frankfort. | 10. Muskegon. |
| 3. Cheboygan. | 7. Grand Rapids. | 11. Niles. |
| 4. Dowagiac. | 8. Jackson. | 12. Trenton. |

brine. Analyses of these brines are given in Tables XX and XXI, the latter being taken from an article by J. W. Turrentine.⁶⁵

63. Filer and Sons, Filer City, Mich. Brines from well 92° by salinometer. Analysis by W. and H. Heim, Saginaw, Mich., 1888.

64. Same. Sample taken from settler, 100° by salinometer.

65. Same. Brine from settler, saturated at 60° F. and then raised to 172° F.

66. Same. Brine from well. Analysis by Dr. F. E. Englehardt, Syracuse, N. Y., September 9, 1889.

67. Same. Settled brine.

⁶⁵ Jour. Industrial and Engineering Chem., Vol. 4, No. 11, p. 832.

TABLE XX.

	63.	64.	65.	66.	67.	68.	69.	70.
Specific gravity	1.138	1.153	1.170	1.1745	1.206	.....	.....	.....
Calcium sulphate	5.660	4.62	4.92	5.566	4.7568	16.74	2.3	3.121
Calcium chloride . . . . .	.....	0.40	2.65	0.168	0.4648	.....	1.0	1.732
Magnesium sulphate	2.015	2.43	trace	1.749	2.9271	0.17	0.7	1.944
Magnesium chloride . . . . .	.....	.....	.....	.....	1.81	0.66	trace	0.800
Sodium sulphate . . . . .	.....	.....	.....	.....	.....	190.16	265.7	290.321
Ferric oxide and alumina	247.400	266.20	256.20	221.789	260.3287	.....	.....	.....
Sodium chloride . . . . .	.....	.....	.....	.....	.....	.....	.....	.....
Total solids	255.075	273.65	263.77	229.262	268.4774	209.54	269.7	297.418

63-69, grams per kilogram; 70, grams per litre.

68. Buckley and Douglas Lumber Co., Manistee, Mich. Analysis by Fred Ruschaupt and Son, Milwaukee, Wis., February 14, 1910.

69. Michigan Salt Co., Marine City, Mich. Analysis by Robt. E. Devine, 301 Park Bldg., Detroit, Mich., July 16, 1910.

70. Port Huron Salt Co., Port Huron, Mich. Analysis by Dr. Chas. D. Aaron, Detroit, Mich., March 13, 1909.

71. Delray Salt Co., Delray, Mich. Artificial brine direct from well. 1911. R. F. Gardner, analyst.

72. Michigan Alkali Co., Detroit, Mich. Artificial brine from well. 1911. R. F. Gardner, analyst.

73. Louis Sands Salt and Lumber Co., Manistee, Mich. Artificial brine from wells. A. R. Merz, analyst.

74. R. G. Peters Salt and Lumber Co., Eastlake, Mich. Composite artificial brine from six wells, contains hydrogen sulphide. 1911. A. R. Merz, analyst.

75. Filer and Sons, Filer City, Mich. Artificial brine from wells. 1911. A. R. Merz, analyst.

76. State Lumber Co., Manistee, Mich. Composite brine from two wells. 1911. A. R. Merz and R. F. Gardner, analysts.

77. Stearns Salt and Lumber Co., Ludington, Mich. Composite artificial brine from four wells. 1911. R. F. Gardner, analyst.

78. Diamond Crystal Salt Co., St. Clair, Mich. Brine from a single well. 1911. R. F. Gardner, analyst.

79. Davidson-Wonsey Co., Marine City, Mich. Brine from two wells. 1911. R. F. Gardner, analyst.

80. Michigan Salt Works, Marine City, Mich. Brine from company's one (No. 1?) well. 1911. R. F. Gardner, analyst.

81. Worcester Salt Co., Ecorse, Mich. Composite brine from two wells. 1911. R. F. Gardner, analyst.

Table XXII, also published by Turrentine,⁶⁶ shows the composition of the mother liquors, or bitterns, resulting from the evaporation of the artificial brines in the manufacture of salt.

82. Delray Salt Co., Delray, Mich. Bittern, drippings from salt as conveyed from vacuum pans. Probably but slight concentration. 1911. A. R. Merz, analyst.

83. Delray Salt Co. Bittern from grainers, 12 days evaporation. 1911. A. R. Merz, analyst.

84. Pennsylvania Salt Co., Wyandotte, Mich. Bittern from dripping vats. 1910. R. F. Gardner, analyst.

85. Diamond Crystal Salt Co., St. Clair, Mich. Bittern from grainer, 23 days evaporation. 1911. R. F. Gardner, analyst.

86. Davidson-Wonsey Co., Marine City, Mich. Bittern, drippings from vacuum pan salt. 1911. R. F. Gardner, analyst.

⁶⁶ Loc. cit. pp. 832-3.

87. Michigan Salt Works, Marine City, Mich. Bittern from grainer, 6 weeks evaporation. 1911. A. R. Merz, analyst.

88. Filer and Son, Filer City, Mich. Drippings from salt. 1911. R. F. Gardner, analyst.

89. R. G. Peters Salt and Lumber Co., Eastlake, Mich. Bittern from grainer, 19 days evaporation. 1911. A. R. Merz, analyst.

90. Buckley and Douglas Lumber Co., Manistee, Mich. Bittern from grainer, 4 weeks evaporation. 1911. A. R. Merz, analyst.

91. Louis Sands Salt and Lumber Co., Manistee, Mich. Bittern from grainer, 3 weeks evaporation. 1911. A. R. Merz, analyst.

92. Stearns Salt and Lumber Co., Ludington, Mich. Bittern from grainer. 1911. A. R. Merz, analyst.

The foregoing analyses show that the Salina brines possess the greatest purity with respect to the sodium chloride, as well as the highest concentration of that salt. They are therefore preferable to all the others for use in the manufacture of salt. It may be seen from the analyses in Table XXII that the potassium chloride content of the bitterns is not as large as might be expected from the composition of the brines before evaporation. Turrentine⁶⁷ believes this to be due to the physical adsorption of that salt by the sodium chloride.

Origin of the Salina deposits. There has been some diversity of opinion as to the origin of the rock salt of the Salina formation. Among the earlier writers, Hubbard⁶⁸ and Lane⁶⁹ have applied the theory of Ochsenius, Lane going into considerable detail and locating the bar, which is the essential factor in Ochsenius' theory, in Ohio. However, according to Schuchert's⁷⁰ map of the Lower Salina, the waters must have passed more largely around through New York and Canada into Michigan, while Grabau⁷¹ believes the breccia and conglomerate, upon the presence of which Lane bases the location of the bar represent, "the talus breccia produced on an extensive land surface of post-Monroe time and that this talus was subsequently incorporated into the lower Onondaga on the resubmergence of this region by the sea."

Grabau and Sherzer,⁷² would follow Walther and assign to aridity the principal role in the formation of these deposits, since they speak as follows:

"Over the Michigan-Ontario-Western New York area, which constituted one or more basin-shaped depressions, the deposition of the Salina muds began. These were derived from the erosion of the earlier

⁶⁷Loc. cit.

⁶⁸Hubbard, L. L., Geol. Sur. Mich., Vol. V, 1895, Part II, pp. ix-xix.

⁶⁹Lane, A. C., *ibid.*, p. 27.

⁷⁰Schuchert, Charles, Paleogeography of North America, Bull. Geol. Soc. Am., Vol. 20, 1908, Pl. 69.

⁷¹Geol. and Biol. Sur. Mich., Pub. 2, Geol. Ser. 1, 1910, p. 29.

⁷²*Ibid.*, pp. 235-6.

marine strata, especially the Niagaran series, which according to all indications had a wide distribution in pre-Salina time. Since the Niagaran is so largely calcareous, the resultant detrital material made more or less argillaceous calcilutites or lime mud rocks. These were carried by the intermittent desert streams to the center of the Salina desert, which was in the Michigan region, and there deposited in shallow playa lakes. This accounts for the fine stratification and other depositional features of these formations. The deposits carried by rivers from the northern Appalachians, were mostly argillaceous and at first predominantly red. These are now found in the lower Salina shales of New York, etc. The salt and gypsum found in these deposits was the old sea-salt imprisoned in the Niagaran and earlier marine strata at the time of their formation under the sea. On exposure of these salt impregnated limestones (the salt in which constituted about one per cent of the mass), to the dry and hot desert climate of Salina time, the salt and gypsum formed as an efflorescence upon the surface of the exposed rocks, and this in rainy periods was washed toward the center of the basin; i. e., the Michigan and New York regions. Here it was deposited on the evaporation of the shallow playa lakes, after the manner of deposition of salt in desert basins of to-day. To produce a salt bed 100 ft. thick and covering an area of 25,000 square miles, which is probably in excess of the area covered by the thick salt beds, it would require the erosion of 100 ft. of marine limestone covering an area of 2,500,000 square miles, or 400 ft. of limestone covering an area of 625,000 square miles, and the concentration of the derived salt in the basin 25,000 square miles in area. Thus for the production of a pure mass of rock salt covering 25,000 square miles, and 100 ft. thick, the erosion of 400 ft. of limestone from Wisconsin, Minnesota, the upper Great Lake region, and the Ontario region west of Toronto would suffice. But since we know, that the thickness of the Niagaran limestone over this region was at least twice 400 ft., not to mention the thickness of the lower marine strata which have also been removed by erosion, it will be seen that the removal of the Niagaran limestones from this area would give a salt mass 200 ft. thick and covering an area of 25,000 square miles or approximately 1,000 cubic miles of rock salt. This is probably much more than the total quantity of rock salt in the Salina of Michigan, while that of Canada, with a total thickness of 126 ft. at Goderich, comprises probably not much over 100 cubic miles of salt, and that of New York perhaps less than half that amount. It is therefore probable, that the Niagara formation alone was able to furnish all the salt found in the succeeding Salina formation, of New York, Ontario, and Michigan."

Schuchert⁷³ also lays emphasis upon the arid climate of the Salina time when he says:

"In the United States, after the Guelph, these seas were very shallow—not normal marine waters. The sedimentary record is one either of red shales with salt and gypsum, or thin dolomites or water limestones. The seas were those of an arid climate, with salt pans and shallow stretches alternately exposed to the effects of the sun, as demonstrated by the sun-cracked 'ribbon limestones' or calcareous shales to be seen in many widely separated places. At last the greater part of these waters subsided, and the Siluric ended with an emergence that was nearly as extensive as the one at the beginning of this period."

From a consideration of the data at hand, it would appear that the latter explanation, that of a desert origin, is the more probable one, since, as pointed out by Grabau,⁷⁴ these occurrences show the characteristics which Walther⁷⁵ has found to be exhibited by desert salt deposits, namely,—the general absence of marine fossils, the limitation of the salt beds to circumscribed basins, the red color of the associated shales, and the mud cracks. In addition to these indications of continental deposits, it seems to the writer that there are at least three other facts which have an important bearing upon the subject but which have not received proper recognition: (1) The general irregularity in the distribution of the beds, (2) the variations from the order of deposition of salts which would be expected from the evaporation of sea water, and (3) the association of the salt (sodium chloride) beds with anhydrite.

If the Salina salt deposits of Michigan had been formed in a basin shut off from the sea by a bar such as demanded by the theory of Ochsenius, a greater continuity of deposits would be expected than seems apparent from a consideration of Table XVIII, and more specifically in the case of the wells of the Diamond Crystal Salt Co. On the other hand, wandering dunes and the dry deltas of torrential streams would afford the depressions in which the more or less localized deposits could be formed.

As has been already indicated, the salt (sodium chloride) is generally underlaid by anhydrite or gypsum, in some instances however resting directly upon the dolomite. If the deposition took place from sea water according to Ochsenius' theory, how could this phenomenon be explained? It could not be argued that the sea of that time was deficient in calcium sulphate, since enormous deposits of that salt occur within the Salina. Walther⁷⁵ has shown that just such occurrences are characteristic of desert salt deposits due to the repeated working

⁷³Loc. cit., p. 149.

⁷⁴Grabau, A. W., *Outlines of Geologic History*. University Press, 1910, p. 80.

⁷⁵Walther, Johannes, *Das Gesetz der Wüstenbildung*, Berlin, 1900, pp. 140-156.

⁷⁶Loc. cit., p. 153.

over of the deposits accompanied by the segregating action of drifting sands. This same action may possibly explain the apparent absence of the "Abraumsalze" from the Salina deposits. If such be the case, it is possible that deposits of these salts may be found by more extensive explorations, unless, as has been suggested as a possibility, they have been eroded during Monroe time and now appear in the form of the Monroe and Dundee brines.

It has been pointed out that Van't Hoff and Weigert⁷⁷ have shown that the relationship between the water tension of the water of crystallization and that of the solution determines whether calcium sulphate shall be precipitated as anhydrite or as gypsum. When the former is the greater, the product is anhydrite, and when the latter is the greater, gypsum is deposited. Since the water tension of both the water of crystallization and that of the solution increases with an increase of temperature, but at different rates; with a solution of given composition, temperature is the controlling factor. The critical temperature for sea water, as determined by Van't Hoff and Weigert, is 25° C (77° F), while that for a saturated salt solution is 30° C (86° F). Although it is impossible to determine the exact composition of the solution from which the anhydrite of the Salina was deposited, the assumption that the presence of anhydrite indicates relatively high temperature for that solution during the deposition, does not seem far fetched. The conditions which would favor such temperature would be aridity, permitting of increased insolation; and exceedingly shallow bodies of water which would permit the penetration of the sun's rays.

The factors just discussed, in connection with the work of other writers, would seem to demonstrate pretty clearly that the salt deposits of the Salina are of continental origin and were formed under arid conditions.

SUMMARY.

The important points brought out by the preceding discussion are:

1. Saline waters are obtainable in Michigan from five horizons,—the Parma, Napoleon, Berea, Dundee, and Upper Monroe.
2. Rock salt occurs in but one formation,—the Salina.
3. The artificial brines of the Salina are superior to all the other brines for the manufacture of salt.
4. The natural brines which are suitable for the manufacture of salt, given in the order of suitability, are the Berea, Napoleon, and Parma.
5. The brines of the Dundee and Upper Monroe limestones have the composition of bitterns and are therefore unsuited for use in the manufacture of salt, but they are important as the mineral waters of

⁷⁷Loc. cit.

the health resorts of Michigan, and offer some possibilities as a source of potash and bromine.

6. The Napoleon and Berea brines are the best suited for use in the manufacture of bromine and calcium chloride.

7. The Parma brines are considered to have been formed by the solution of disseminated salt within the underlying gypsiferous Lower Grand Rapids series and to have been forced up, under hydrostatic pressure, along fractures into the Parma.

8. The Napoleon brines are believed to have their origin in the solution of disseminated salt within the underlying red shale layer which is considered to represent the basal member of the Upper Marshall rather than the upper member of the Lower Marshall. They may also in part represent the original sea water in which the Napoleon was laid down.

9. The Berea brines may have been formed either through the solution of disseminated salt within the Antrim or Coldwater shales or they may in part represent original sea water.

10. The Upper Monroe brines may possibly have been formed through the erosion of that portion of the Salina which contained the mother liquor salts. The Dundee brines in turn may have been formed through the erosion of the Monroe.

11. The beds of rock salt within the Salina formation are believed to have been formed as continental deposits, an arid climate, with its attendant agents of weathering and transportation, being the essential factor in their deposition.

CHAPTER IV.

SALT MANUFACTURE.

WELLS.

With the exception of the rock salt obtained from the shaft of the Detroit Salt Co., located at Oakwood, near Detroit, salt is manufactured in Michigan by the evaporation of brines, both natural and artificial, obtained from wells. The subject of manufacture should, therefore, properly begin with a discussion of wells.

*Well-drilling machinery.*¹ In the drilling of wells, two different methods of procedure are employed. One consists in erecting and equipping the derrick-house before beginning operations; the other in putting down the well with a portable rig and then constructing the derrick-house after the drilling has been completed. In the first, the well is drilled for a contract price which includes the complete equipment ready for operation; in the second, the drilling is paid for at so much per foot.

The derrick-house and equipment, a plan of which is shown in Fig. 22, consists of a derrick for raising and lowering the tools in the well, and a boiler and engine, the engine operating a walking-beam, to which the tools are connected by an hemp or steel wire cable. The tools employed are the rope socket, sinker bar, jars, auger stem, and bit (see Fig. 23). All of these tools may or may not be placed in the string, depending upon the conditions under which the well is sunk.

The rope socket consists of a steel bar several feet long, in one end of which the cable is fastened. In the other end is a bevel screw socket by means of which the other tools may be attached.

The sinker is a steel bar six to sixteen feet long, the purpose of which is to add weight and length, and so assist in sinking the tools and in keeping the hole straight. It is not used as often as formerly, except in the case of wet holes which require the frequent removal of the tools. In such a case it hastens the sinking of the tools against the bouyancy of the water.

The jars consist of a pair of linked steel bars which, on the upward stroke of the walking beam, exert a jerk upon the drill and so loosen it

¹A very complete report on well-drilling methods has been published recently by the U. S. Geological Survey as Water Supply Paper No. 257.

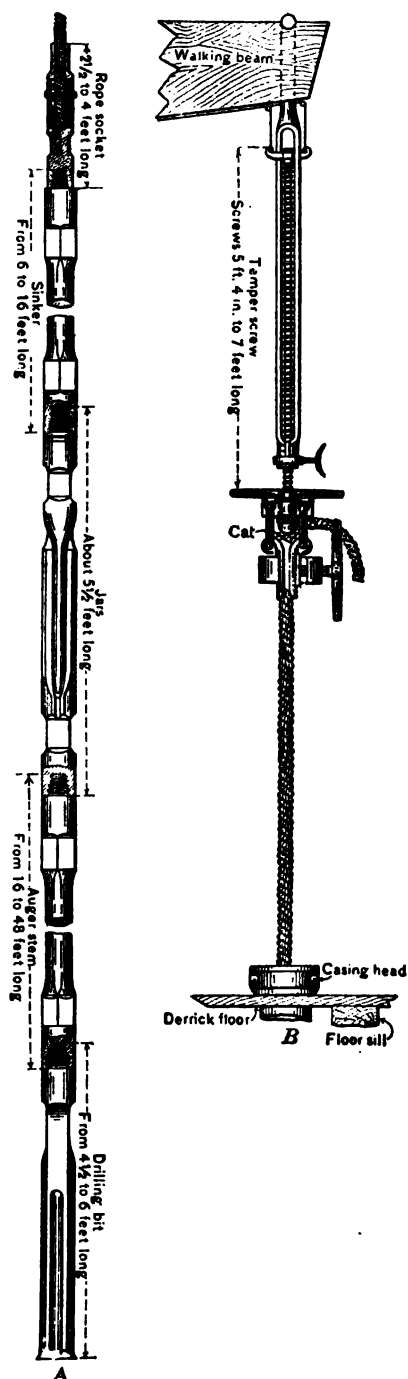
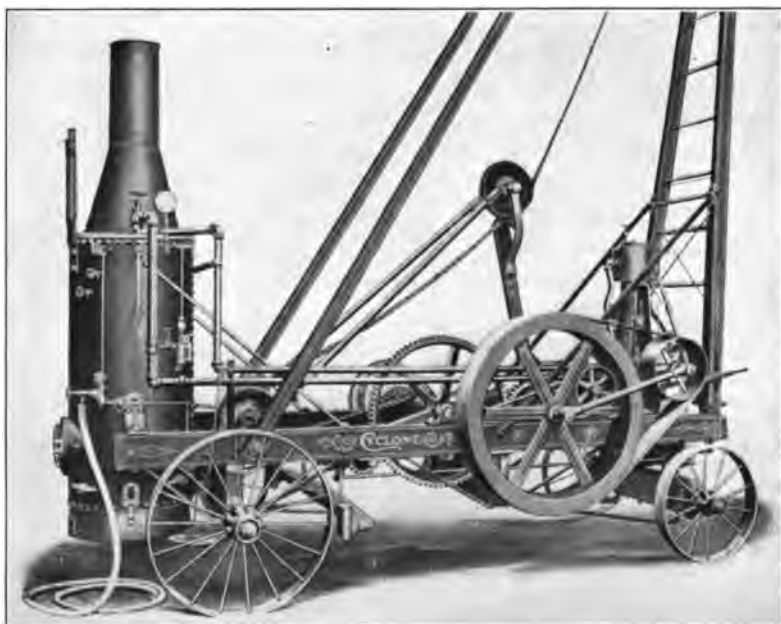


Figure 23. Showing the tools used in well drilling (after Bowman). U. S. Geological Survey Water-Supply Paper No. 257.



A PORTABLE WELL-DRILLING RIG.

from the rock. The jars are not used to increase the effectiveness of the blow, but the length of the cable is so adjusted that the upper jar strikes the lower one only on the upward stroke. The jars are generally used only when drilling in rocks which do not chip readily and are therefore liable to imprison the drill.

The auger stem is a steel bar similar to the sinker bar and is placed just above the bit. By increasing the weight and length of the drill it performs two functions. The weight increases the effectiveness of the blow and the length keeps the hole straight.

The bit is a steel bar five to six feet long, sharpened at one end. There are a number of patterns in use, one of which may be seen from Fig. 23.

The pumping motion of the walking-beam causes the tools to rise and fall on the rock, thus breaking it up. In the earlier stages, it is necessary to twist the drill by hand so that it will strike in a different place each time and thus produce a round hole. After a depth of several hundred feet is reached, the torsion in the cable, induced in pulling it free from the rock, is sufficient to turn the drill without any attention from the driller. In dry wells, it is necessary to introduce a small amount of water to facilitate the drilling and also the removal of the material.

The fine materials which have been produced by the drill are removed by a bailer or sand-pump. The bailer consists of a tube of varying length, in the bottom of which is placed a valve which allows the water and powdered rock to enter and be drawn to the surface. If the drillings are thick and do not enter the bailer readily, the sand-pump is employed. This differs from the bailer in that it contains, in addition to the valve, a plunger which can be operated from above to suck the material into the tube.

The portable rig consists essentially of the same features as those described for the permanent outfit, except for the modifications necessary to render it movable. These machines are manufactured by a number of concerns and the general character may be seen from Plate I.

Well-boring methods. In beginning a well, a ten inch pipe is usually driven into the ground as far as possible. Inside of this, an eight inch pipe is sunk as fast as the drift material overlying the solid rock is broken up and removed with the bailer or sand-pump. The eight inch casing is carried to bed rock, at which point, the size of the hole is reduced to six inches and the well is continued uniformly to the desired depth. Whether the six inch casing is continued to the bottom of the well or not depends upon the firmness of the rock through which the well passes and also upon the necessity of shutting off flows of fresh water which might reduce the strength of the brine. It will be readily

apparent that, in wells pumping natural brines, casing practically always will be necessary, inasmuch as fresh water channels nearly always exist above the brine-bearing stratum. On the other hand, where artificial brines are employed, if the rock is firm enough to prevent caving, so that no casing need be used, the influx of fresh water may be sufficient to dissolve the rock salt without the necessity of pumping water into the well.

Pumping methods. Three methods of pumping brines are in use, namely,—the plunger pump, pumping with compressed air, and pumping with water pressure.

The plunger pump is never used where it is necessary to pump water into the well to form the brine. The pump itself is an ordinary lift-pump and is operated by a walking-beam. The depth at which the valve is placed depends upon the height to which the brine rises in the well.

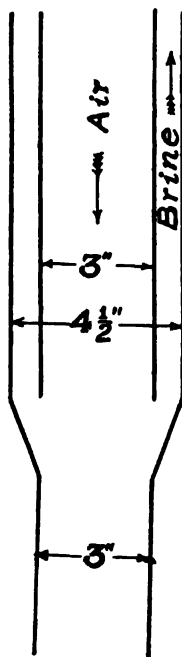


Figure 24. Showing one method of piping for pumping with compressed air.

The method of pumping with compressed air, although subject to minor variations in practice, may be described as follows: Tubing somewhat smaller than the bore of the well is lowered to the bottom. Inside of this, another set of tubing is placed, the depth to which it goes depending upon the height to which the water rises in the well. Air

is then forced down the inner tube and allowed to rise through the outer one carrying with it the brine which is above the lower end of the air tube. This process may perhaps be better understood from Fig. 24. In this case we have a four and an half inch tube tapering to a three inch. The inner tube which is three inches in diameter, extends down to the point where the outer tube begins to taper. This system is reversible, that is, the air may be forced down the inner tube and the water allowed to rise through the outer tube, or the outer tube may be used as the air pipe. The above is the modification of the method which is very largely employed in the Ludington and Manistee districts. The air line in these wells extends down to a depth of seven hundred to a thousand feet and an air pressure of two hundred and seventy-five to three hundred pounds per square inch is employed.

Pumping with water pressure is the method employed by most of the companies operating along the Detroit and St. Clair rivers. This method is especially adapted to those conditions under which it is necessary to pump water into the wells in order to dissolve the rock salt; and consists in pumping water down one pipe under sufficient pressure to cause the brine, which has been formed, to flow from the other tube. When the cavities formed by the solution of the rock salt, have reached such a size that two of them unite it is customary to pump the fresh water into one well and allow the brine to flow from the other.

As to the efficiency of these different methods, the plunger pump is probably the least efficient. When a number of wells are in operation, each well must have its own power plant with a man to operate it; or the steam must be piped from the central power plant, affording an excellent opportunity for loss either by leakage or condensation or both. Furthermore, the plunger pump requires greater supervision than does either of the other methods. The air and water pressure methods have the advantage of operation from a central plant, are cheaper in operation, and possess a greater efficiency. The water pressure system is preferable where it is necessary to pump water into the wells, the air pressure where the natural flow in the rocks is sufficient to produce the desired amount of brine. The use of water is more advantageous than air in one respect, that is, it does not exert the pounding effect of the air and is not so liable to injure the tubing.

PRELIMINARY TREATMENT OF THE BRINES.

The treatment of the brine before evaporation depends very largely upon its composition and the method of evaporation to be employed. Practically no brines, either natural or artificial, are free from impurities, as may be seen from the analyses already given. The first

problem which confronts the manufacturer is to remove, in so far as it is economically possible, these impurities. Aside from whatever mechanical sediment there may be, there are also two chemical impurities, less soluble than the sodium chloride, which may be present. These two compounds are ferrous carbonate and calcium sulphate. The more soluble impurities are very largely left in the mother liquors after the sodium chloride has been removed.

The brine as it comes from the wells is pumped into cisterns where it is allowed to settle, thus removing the foreign matter which is held in suspension. The cisterns differ somewhat in size and shape, some being circular and others, rectangular. An example of the rectangular type, which is the more common form, is shown in Plate IIA. They are built of planks two or three inches in thickness, gripped together and calked to prevent leakage.

If the brine contains iron in the form of the ferrous carbonate, slaked lime is added in the form of a paste to cause its precipitation. There are two methods of adding the lime. It may be added to the brine in the settling cistern, or the brine from the well may be caused to pass through a liming-house before reaching the cisterns. The liming-house² consists of a pyramidal-shaped tower about fourteen feet square at the base, in the top of which is a vat for slaking the lime, which is added to the brine as it enters at the top of the house. The brine, to which the lime has been added, then passes down over or through a series of trays placed one above another about a foot apart. Some of the trays consist merely of rows of slats while the others are made of perforated boards. The action of the trays, in breaking up the stream, gives a greater opportunity for aeration and oxidation, thus hastening the precipitation of the iron. From the liming-house, the brine is conducted to the cisterns through a series of open troughs, in the bottom of which are placed a series of riffles to further aid the aeration.

As a rule the brine is conducted from the cisterns to the preheaters, or hot settlers, if they are employed in the process. In one instance, that of the North American Chemical Co., Bay City, a filter is interposed between the cisterns and the preheaters. This filter is composed of a circular tank about ten feet in diameter and seven feet high filled to near the top with excelsior. On top of the excelsior is placed a wooden diaphragm. The brine flows by the force of gravity from the cisterns into the base of the filter and up through the excelsior onto the diaphragm, from whence it is drawn off into the preheaters, if it is to be used in the grainers, or is conducted directly to the pans if the vacuum pan process is to be employed. These filters have been found to be very efficient

²The liming-house described above is that of the North American Chemical Co., Bay City, Mich.

and require cleaning only about twice a year. To clean the filters a stream of fresh water is forced through them from the top.

The preheaters, with one important exception to be noted later, are rectangular vats, sixty to one hundred and twenty feet long, eight to sixteen feet wide, and six feet deep, with steam pipes in the bottom. They are supposed to perform several functions, namely,—to complete the settling of the insoluble matter, to precipitate the gypsum, and to bring the brines to saturation. That they are of very low efficiency in removing the gypsum is shown by the following analysis of the refuse from a preheater made by F. Ruschaupt and Son, and very kindly furnished by the R. G. Peters Salt and Lumber Co., Eastlake.

ANALYSIS MADE FEBRUARY 11, 1908.

Sodium chloride.....	94.965%
Calcium sulphate.....	1.931
Calcium chloride.....	0.082
Magnesium chloride.....	0.056
Moisture.....	1.645
Insoluble matter consisting of very little fine free silica, aluminic silicate, and a little oxide of iron.....	1.333
Total	100.012

The superintendent of one of the largest plants in the state informed me that the retention of the preheater was largely a matter of sentiment, old salt makers believing it impossible to make good salt without preheating the brine. In the case of unsaturated brines, leakage might be produced in the grainers through the solution of the salt in the cracks. The increasing use of cement in the construction of grainers, however, will probably soon remove this excuse for the existence of the preheater.

The most effective means of removing the gypsum is the precipitation by means of chemical reagents. Of these, the most important are sodium bicarbonate, and sodium dihydrogen phosphate. The latter is the more efficacious of the two, but it is also the more expensive. The question of which, if either, of the compounds should be used may be best determined by experimentation. The factors to be considered in such an experiment are, the composition of the brine, the purity of the salt desired, and the cost of the materials.

THE EVAPORATION OF THE BRINE.

After the brine has been prepared, as described above, it is then ready for evaporation. Inasmuch as there have been many advances in the methods of carrying out this portion of the process of manufacture, it might be well to review briefly the history of this development.

Historical. The process of evaporation first employed at Saginaw was known as the kettle process. The potash kettle was used and a

series of kettles, finally reaching fifty to sixty in number, was placed between the furnace and the chimney. With this large number of kettles, the fire required to heat the back kettles was much too hot for those over the furnace. To overcome this, arches were built under the first ten or fifteen kettles. While this protected the kettles, it did not tend to an economy of fuel. The question of fuel, however, was not as important at that time as now, most of the blocks using the offal from the saw mills. It was therefore undoubtedly other disadvantages, (such as the difficulty in the control of the kettles and in the removal of salt; the non-uniformity of the product due to the different rates of crystallization, and the small production) which early led to the substitution of the pan and grainer processes. Since both of these processes, although somewhat modified, are still in use they will not be described at this point.

Another process, which was early employed in the Michigan industry, was solar evaporation. In this process, the heat of the sun is made use of in driving off the water from the brine. The evaporation is accomplished in a series of vats, or "covers," so called because each vat is provided with a movable roof which can be rolled on or off according to the demands of the weather. On account of the slow rate of crystallization, the salt crystals formed by this process are very large and hard. They therefore dissolve very slowly, making the solar salt more effective for certain purposes, such as packing fish, than that produced by artificial heat, and permitting it to command a higher market price. This process was not economically successful in Michigan and the last solar field, located at Zilwaukee, between Saginaw and Bay City, was abandoned some years ago.

That attempts at improved methods of manufacture were made early in the history of the Michigan industry, is shown by the patents granted for the same. Among these were the Chapin patent, granted March 18, 1862, and the Garrison Process, patented August 19, 1862. While neither of these processes gained any pronounced degree of success, yet they are historically interesting as showing the trend of the industry.

The following description of the Chapin process, invented by Nathan Chapin of East Saginaw, Michigan, is taken very largely from the *Scientific American*.³ A typical plant, minus the power house is shown in Fig. 25. In the center of the building is a large vat, which is traversed throughout its entire length by two tubular furnaces, DD; floating on the brine in the first vat is a second triangular vat, (shown by the dotted line), traversed by a tubular furnace, H. The brine is drawn into the large vat at faucets in the hotter portion of the furnace.

³Scientific American, Vol. VII, New Ser. p. 97.

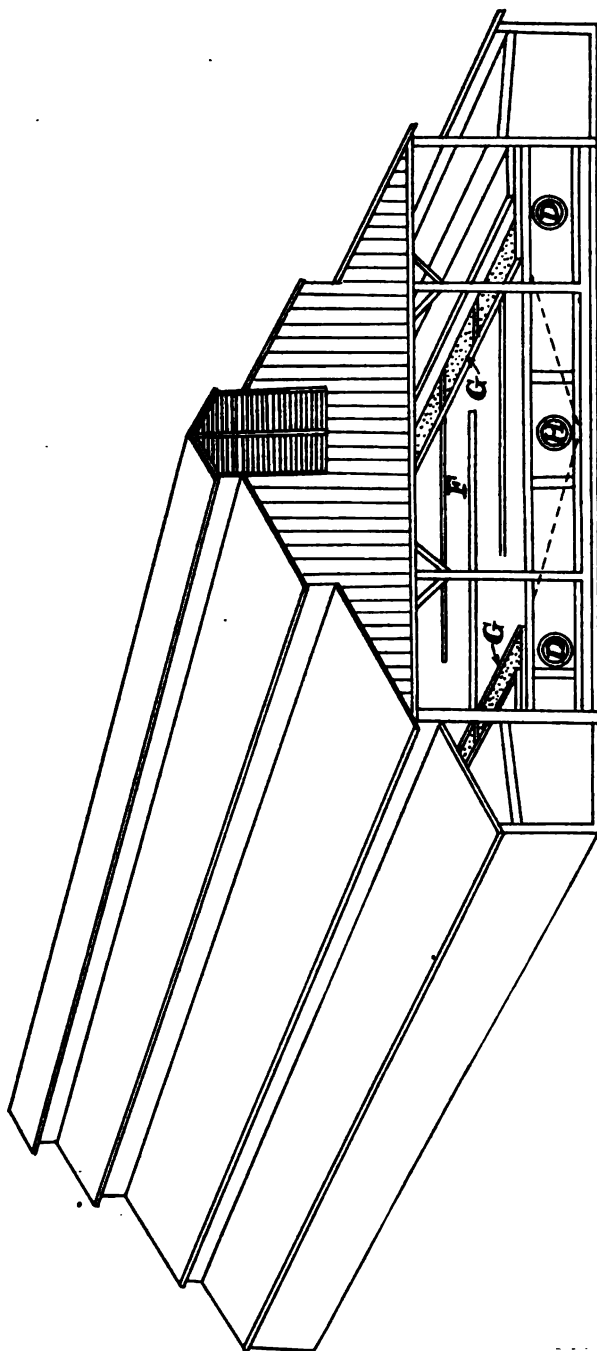


Figure 25. Showing salt block operated by the Chapin process (after the Scientific American).

By the evaporation which takes place a current is maintained toward the rear of the vat, the less soluble impurities being deposited on the journey. At the rear of the large vat the brine flows into the upper vat, where the evaporation is completed. The upper vat being fitted with partitions, F, the brine takes a zig-zag course to the front of the vat, depositing the salt on the way. As often as necessary, the mother liquor, is drawn off at the front of the vat. The salt which is deposited on the slanting bottom of the upper vat is raked onto the perforated platforms, GG, where the brine is allowed to drain back into the lower vat. The impurities which adhere to the salt are washed off by the condensation of the steam upon it.

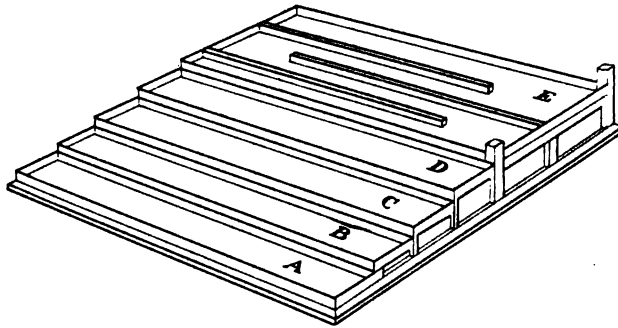


Figure 26. Showing the Garrison process (after the Scientific American.)

The Garrison process was patented by C. O. Garrison of East Saginaw. This description is also from the Scientific American. Fig. 26 represents a complete plant. The vats A, B, C, D, in which the brine is evaporated, are constructed with double bottoms to permit of the circulation of steam or hot air. Before the brine is run into the vats for final evaporation, it is partially evaporated in the large vat, E, containing partial partitions alternating from either end and thus compelling the brine to take a zig-zig course. This vat is also supplied with a double bottom so that the brine may be heated here and its clarification hastened. When the evaporation in the evaporating vats has been carried to the proper point, the mother liquor is drawn off and the salt allowed to dry in the same pan.

Another process which was employed at this time, at least on a small scale, was that known as the Kanawha process, from its use in the Kanawha valley in West Virginia. This process may be considered as the forerunner of the present grainer process. With certain modifications, it is still in operation in West Virginia and may be described briefly as follows:⁴ the plant consists of three parts, the furnace, settlers, and grainers.

⁴Grimsley, G. P., W. Va. Geol. Sur., Vol. IV, p. 304.

The furnace is made of cast iron pans, eight to ten by three feet, bolted together and thus forming a section. Over the section is placed a wooden steam chest so constructed as to be steam and water tight. A number of these sections are placed side by side on the furnace walls and the preliminary evaporation is produced by the application of direct heat.

After the brine has been concentrated to a certain extent in the furnace, it passes into vats or settlers, about ten feet wide, one hundred feet long, and three to four feet deep, in which the brine is settled and saturated. The heat is supplied by passing the steam, which is formed in the furnace, through copper pipes placed in the settlers. From the settlers, the saturated brine passes into the grainers, which differ from the settlers only in depth, being about one half as deep. Here the salt is allowed to deposit.

As already stated the kettle blocks soon gave away to the pan and grainer blocks, the former gradually yielding in importance to the latter, until at the present time but three pan blocks are left in the state. Neglecting, for the present, improvements in grainer methods, the next step in the development of evaporating methods may be said to be the introduction of the vacuum pan into the salt industry, and finally the joining of the vacuum pans in a series. As the vacuum pan is to be described under the subject of present methods no further mention of it need be made here.

Present methods. On the basis of the method of applying the heat, the present processes may be divided into two classes, as follows:

1. Evaporation by the direct application of heat.
2. Evaporation by the use of steam, either exhaust or live.

Direct heat methods. At the present time, the only process in use in Michigan which employs direct heat is that of evaporation in open pans. The open pan process is a direct development from the kettle process. The pans are made of quarter inch boiler plate iron riveted together. At first, the pans were ninety to one hundred and twenty feet in length, divided into sections thirty to forty feet long, twelve to fifteen feet wide and ten to twelve inches deep, supported on three walls. In some cases, the pans had perpendicular sides, the salt being raked to the side of the pan and lifted with a shovel; in others, the sides of the pan were sloping and bolted to the draining boards so that the salt could be raked directly onto them. The heat was furnished by a furnace placed at one end about three feet below the pan, the bottom of the flue gradually rising toward the back end of the pan where it passed into the chimney.

The present pan block consists of a number of pans eighty to ninety feet long, eighteen to twenty feet wide, and about twelve inches deep with flanging sides bolted to the draining boards, which are about

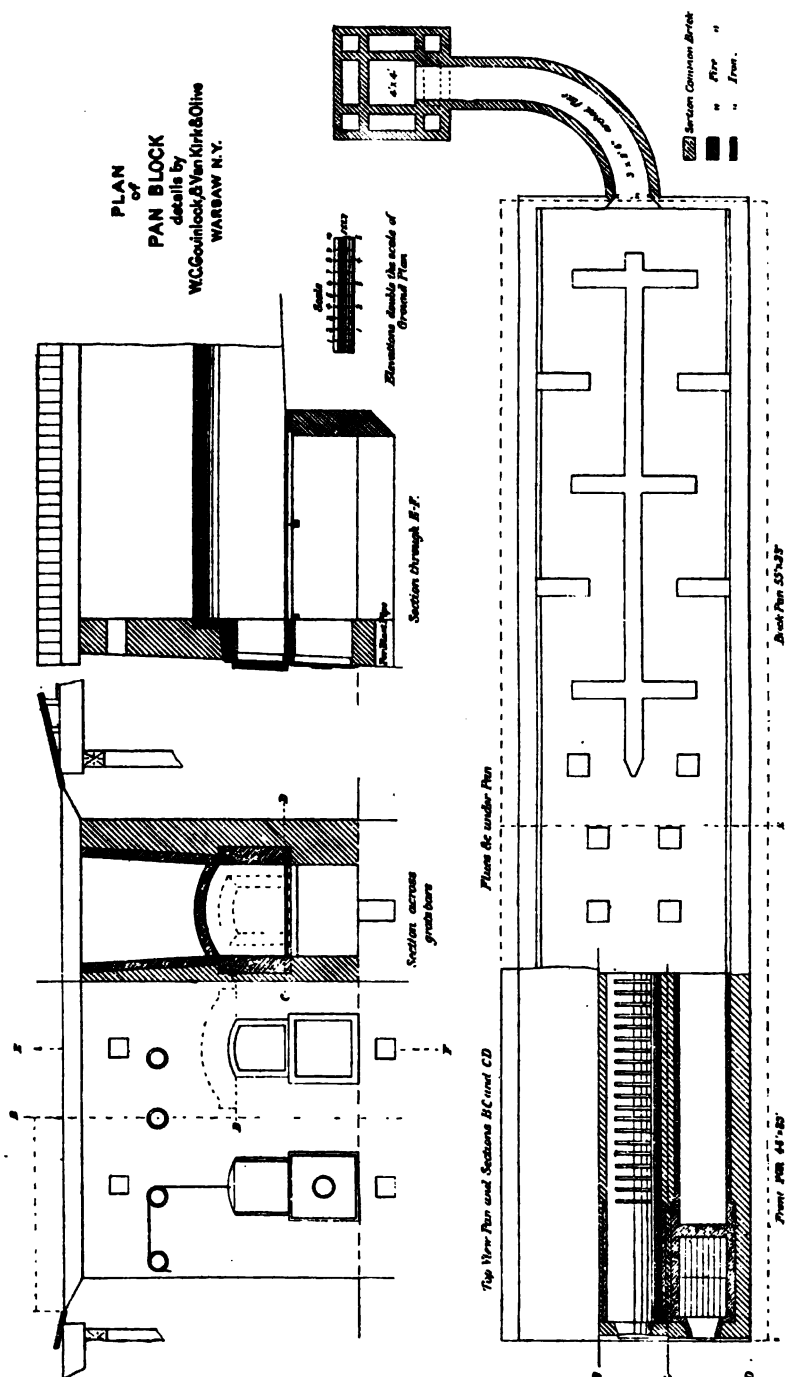


Figure 27. The open pan (after Chatard). U. S. Geological Survey, Seventh Annual Report, 1885-1886.

three feet wide and inclined toward the pans. Between the draining boards of two pans is a walk, six to eight feet wide from which a man operates the rake. As the evaporation takes place at or near the boiling point, the formation of salt is very rapid, and should be removed as fast as formed. This constant removal of the salt is necessary not only to prevent its baking but also because, when left, it forms a coating which retards the conduction of the heat to the brine and therefore increases the fuel consumption per barrel of salt made.

Two methods of applying the heat are now in use. In one the heat passes from the furnace at the front to the chimney in the rear as in the case of the earlier plants. In the other, the space under the pan is partitioned off into three flues. Two of these pass from the furnace to the back of the pan, where they open into the third flue which returns the smoke and heated gases to the chimney, located beside the furnace. The plan of an open pan is shown in Fig. 27.

In the earlier days of the salt industry of Michigan, the pan blocks were operated in connection with saw mills, the refuse from which was used for fuel. At the present time all of these blocks are operated independently and use coal entirely.

Steam evaporation. Steam is employed as the evaporating agent in three different processes, namely,—the grainer, Alberger, and vacuum pan.

GRAINER SYSTEM. Grainers may be described in general as shallow vats in the bottoms of which are placed series of steam pipes. However, they present certain variations in size, shape, materials out of which they are constructed, the manner of piping, and the methods of lifting the salt.

The most common type of grainer is rectangular in form. Another type which is also in use is known as the V-shaped grainer on account of the fact that its cross section resembles that letter.

In size the rectangular grainers vary from forty to one hundred and sixty feet in length, from eight to eighteen feet in width, and from fourteen to twenty-four inches in depth. The characteristic size is one hundred and twenty feet by twelve feet by twenty-two inches. The V-grainers are about one hundred and twenty feet long by twelve feet wide at the top and possess a maximum depth of six to seven feet.

With respect to materials, wood, wood and tile, cement, iron, and steel are variously used in grainer construction. The older grainers were constructed of planks three or four inches thick, keyed together and well calked. In some instances, the wooden grainers have been lined with tile. This not only helps to protect the wood but also gives a smoother surface from which to remove the salt. In a number of instances, iron and steel have been used in grainer construction, es-

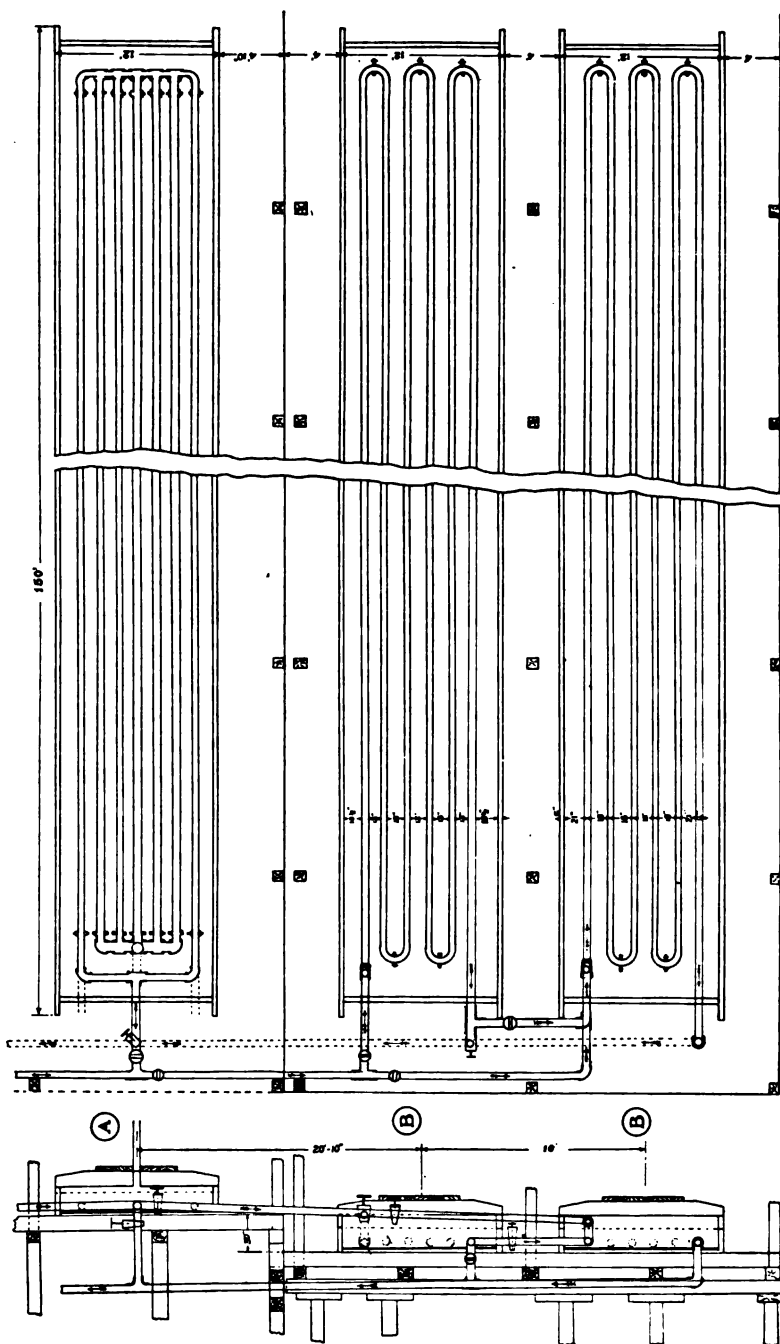


Figure 28. Showing the piping of grainers, both for steam (A), and tall water (B) (after Hubbell).

pecially in the case of the V-shaped grainers. Although the brine does not seem to have any injurious effect upon the metal while in contact with it, yet on exposure to the air it exerts a decided corroding action. The material which at present is gaining popularity, is cement. The first attempts in the construction of cement grainers were failures, owing to the fact that they were held rigidly by the supports. This did not permit of the accommodation of the alternate expansions and contractions brought about by the fluctuations in temperature within the grainer. The result was a cracking of the cement and a rapid destruction of the grainer. Provision has now been made for the expansion and contraction by setting the grainer upon a sand bed.

The manner of piping grainers can best be understood from Fig. 28. This figure, which was very kindly furnished by Mr. J. J. Hubbell of the Buckley and Douglas Lumber Co., Manistee, shows one grainer piped for steam and two for tail water, that is, the water which is formed by the condensation of the steam in the pipes of the regular grainers.⁵

Two methods of lifting the salt are in use. In some grainers, the salt is lifted with a shovel. A walk four to five feet wide runs down the center of the grainer, and onto this the salt is shoveled every twenty-four to forty-eight hours, depending upon the rate of evaporation, and after being allowed to drain, is shoveled into carts and is carried into the stock house. A grainer of this type is shown in Plate II B. Other grainers are provided with automatic rakers. There are several varieties of rakers used. Among these may be mentioned the endless chain, and the reciprocating rakers.

The endless chain raker consists of two chains placed at the sides of the grainer and running over cogwheels at either end. At regular intervals sweeps are attached to the chains. The sweeps pass along the bottom of the grainer, beneath the pipes and up an incline draining board at one end, moving the salt with them, and then returning to the other end of the grainer in the air. As the salt accumulates on the draining board it is gradually pushed over the upper end, either into a conveyor or onto the floor, from whence it is wheeled to the stock room in carts. This method has the disadvantage of exposing the chains alternately to brine and air and so tends to corrode them very rapidly. This not only decreases the life of the apparatus but is also liable to give a red tinge to the salt and so lessen its value.

The nature of the reciprocating raker may be perceived from a study of Fig. 29, which is reproduced from an article on salt manufacture by Geo. B. Willcox⁶ of Saginaw. Mr Willcox describes the apparatus as

⁵In a number of plants the practice is made of placing at the end of a series of grainers piped for steam another grainer through which the condensed vapors are passed to utilize the heat left in the water. This grainer is at a lower elevation than the others so that the water is moved by the force of gravity. On account of the lower temperature, the evaporation is much slower and a correspondingly coarser grade of salt, known as packers, is produced.

⁶Loc. cit.

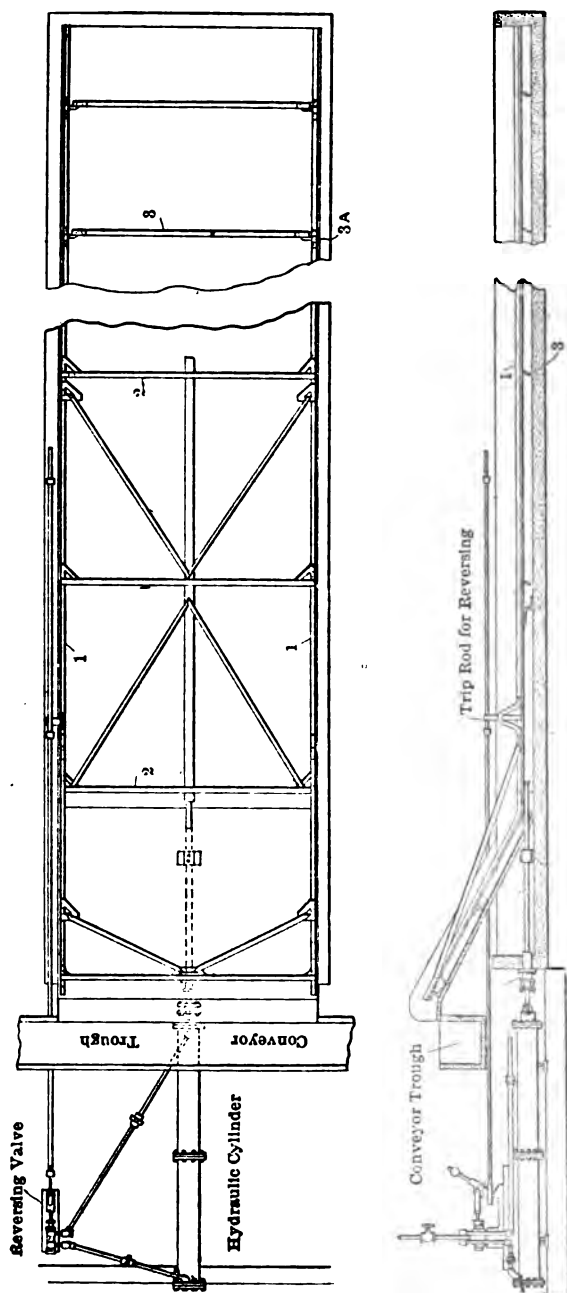


Figure 20. Automatic salt raker, with hydraulic drive (after Willcox).

follows: "The raker consists essentially of a frame-work comprising two steel angles (1) located within the grainer near the bottom and adjacent to the side walls. At intervals these two angles are connected by cross braces (2) and the frame-work so formed carries a series of feathering scraper blades (3) extending transverse the grainer and supported at their two ends on the two side angles by means of horizontally-projecting rocking pivots or fingers (3A)." By means of a steam or hydraulic cylinder the raker is operated with a forward and back movement, the sweep pushing the salt along the bottom and up the inclined draining board at the end, on the forward movement, and feathering on the back stroke, the salt is thus gradually removed from the draining board as in the case of the endless chain raker.

Most plants using the grainer system are run in connection with some other manufacturing concern and utilize the exhaust steam from the same. The temperature of the brine is therefore considerably below the boiling point. Where the supply of exhaust steam is adequate, the temperature runs from 170° to 190°F. but in many cases it falls considerably below these figures. Several plants use live steam in their grainers, coal being employed as the fuel. This imparts to the brine a temperature which is at or near its boiling point depending upon the pressure at which the steam is carried.

As evaporation proceeds, the surface layer of the brine becomes supersaturated and the salt separates out. If the crystallization is rapid and the brine is not agitated, there is a tendency for a film of crystals to form at the surface, retarding the further evaporation. To aid the subsidence a small amount of tallow or cotton-seed oil is sometimes added to the brine, or the brine is agitated from time to time, either by hand or by means of paddles operated by the rakers. When live steam is used the evaporation is generally so rapid that the film tends to break up almost as soon as formed.

ALBERGER SYSTEM. In this system the brine is pumped from the cistern into the heaters, which consist of cylindrical steel shells containing a number of tubes, resembling the flues of a boiler, through which the brine is forced and is heated by steam under pressure. The high heat causes the deposition of gypsum on the walls of the tubes necessitating frequent cleaning. This is accomplished by removing the top of the heater and drilling out the tubes.

From the heater the superheated brine is forced through a rock filter, to remove the gypsum. In shape the filter very closely resembles the tube mill used in cement plants for grinding cement, and consists of a hollow steel shell supported at either end by bearings so that it may be revolved. The shell is partially filled with pebbles and the hot brine being forced through deposits the gypsum on the pebbles. When the

accumulation of gypsum has reached the point where its removal is necessary, the brine pipe is removed, fresh water is let in, and the filter revolved. The revolution of the filter causes the pebbles to pound together, thus loosening the gypsum, which is then washed out.

After passing through the filter, the brine passes into an evaporator, which is merely an air dome and serves to reduce the pressure, and then into the pans. The temperature of the incoming brine is about 226°F. and after making a complete circuit of the pans it passes back into the heater at a temperature of 170°-200°F.

The plan of the evaporating pan is shown in Fig. 30. The brine enters at (D), is swept around the pan by the rakers (A), and flows out at (C). The salt is also moved along until it drops into a well at (B). The pans are eighty-eight by forty-four feet by twelve inches and are constructed of steel.

The salt having fallen into the outlet is let down, in the form of a paste, into a centrifuge where it is whirled for about three minutes and then, in the only plant using this process, passes into the dryers and thence to the separators.

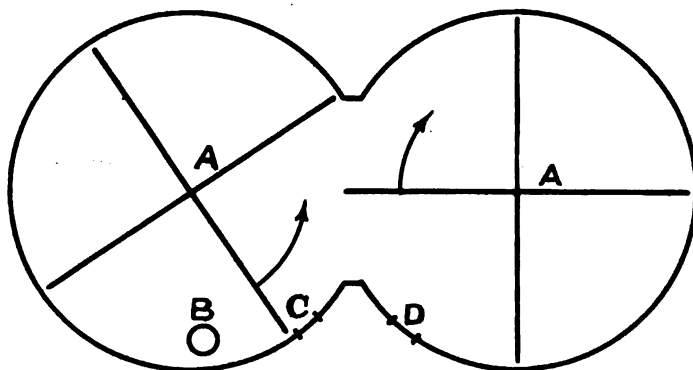


Figure 30. Plan of the Alberger plan.

VACUUM PAN PROCESS. Although the vacuum pan had long been used in the manufacture of sugar and other products, according to Mr. Geo. Ray,⁷ its first application to the salt industry was in 1887, when a pan was erected by Mr. Joseph Duncan at Silver Springs, N. Y. A year or two later, two small pans were built at Ludington for the Butters and Peters Lumber Co. This was followed by a number of "single effect" pans, and in the early nineties, Mr. Peters conceived of the idea of joining two pans in a series, the steam for the second pan being formed in the first. The plans and details were worked out by Mr.

⁷Personal communication.

Geo. Ray and the first "double effect" pan for the manufacture of salt was erected in 1895 at the plant of the R. G. Peters Salt and Lumber Co., Manistee, by the Manistee Iron Works. In 1904, the Manistee Iron Works constructed for the Salt Union of England, Winsford, Cheshire, the first "triple effect" pan, and in 1907, the first "triple effect" pan in Michigan was erected for the Anchor Salt Co., Ludington. It is also interesting to note that in the same year the first "quadruple effect" pan was built at Ludlowville, New York. The only "quadruple effect" pan in Michigan was erected for the Rapid Evaporator Co., at the Plant of Stearns Salt and Lumber Co., Ludington, in 1910-11.

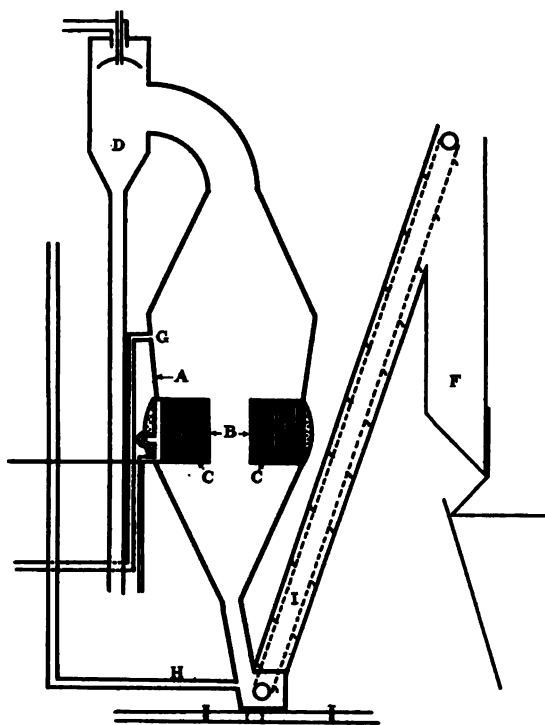


Figure 31. Section of a vacuum pan (after Hubbell).

The principle involved in the vacuum pan evaporation is that of decreasing the pressure on the surface of the brine so that the boiling point is correspondingly lowered. While the pans, in which the evaporation is carried on, differ in some of the minor details, the general principles of the process may be seen from Fig. 31. The pan consists of a steel cylinder (a) tapering at both ends, the upper and lower portions of which are separated by the steam belt (b) through which pass

the copper tubes (c) to permit the circulation of the brine and also to increase the heating surface. The steam is supplied through the inlet (e) and the condensation escapes at (d). The brine is supplied from the cisterns to the pan at (g). When there is no vacuum on the pan it may be filled through the pipe (h) which connects with a brine tank placed at a sufficient height to cause the brine to rise in the pan to the desired point. The steam formed in the pan by the evaporation of the brine is condensed in the condenser and the salt as it forms falls to the bottom of the pan and is removed by the bucket elevator (i). The salt is dumped into the bin (f), where it is allowed to drain and then is carried to the stock room in carts.

When two or more pans are run "multiple effect" the steam formed in the first pan, instead of passing to the condenser, is conducted to the belt of the second pan, on which a greater vacuum is carried, and supplies the heat for the evaporation. Likewise the steam formed in the second pan is carried to the belt of the third and so on.

The following records of the pans at the R. G. Peters Salt and Lumber Co., give an idea of the vacuum and temperature of the steam on entering and leaving the pans.

	Vacuum.	Temperature.	
		Belt.	Elboe.
Pan No. 1.....	10 in.	234°F.	204°F.
Pan No. 2.....	20 in.	191°	170°
Pan No. 3.....	27.7 in.	160°	122°

Pressure in belt No. 1, 10 pounds.

It must be kept in mind that the values for pressure and temperature given above will fluctuate depending upon the steam supply, the freedom of the pans from gypsum, etc.

The advantage of the "multiple effect" over the "single effect" pan lies in the fact that there is a greater utilization of the heat of the original steam, which is used only in the first pan. According to Mr. Geo. Ray, one ton of coal evaporating 16,000 pounds of water will make two tons of salt in a "single effect" pan, four in a "double effect," six in a "triple effect," and eight in a "quadruple effect." In some plants the pans are operated with live steam, in others exhaust steam is employed.

Some experiments performed by Mr. J. J. Hubbell at the plant of the Buckley and Douglas Lumber Co., Manistee, show that when run in moderation the fuel and brine costs per barrel are much lower than when the pans are crowded. The actual results obtained are as follows:

To make 700 barrels in 11 hours.	
Steam—485,987 B. T. units of heat, cost approximately	4.80c per bbl.
Brine—105 gallons, cost approximately	5.02
Total	9.82c
To make 1,000 barrels in 11 hours.	
Steam 668,943 B. T. units of heat, cost approximately	6.7c
Brine—150 gallons, cost approximately	7.5
Total	14.2c

TABLE SALT.

In order to prepare the salt manufactured by the above processes, for human consumption further treatment is necessary. The crude salt is first passed through dryers, which are rotary kilns about thirty-five feet long and six feet in diameter, with a steam cylinder about three feet in diameter running through the center. The kilns are slightly inclined so as to cause the salt to move slowly from one end to the other. Meanwhile a hot air blast is blown through the kiln in the opposite direction to that in which the salt is moving. The kilns turn at the rate of about twelve or thirteen revolutions per minute and it requires about twelve minutes for the salt to pass through the kiln. The temperature varies but is usually maintained at about 240°-250° F. The dried product is next elevated to hoppers from whence it passes into the screens or separators. The screens are in the form of cylinders of wire cloth of different sized mesh, joined end to end, and placed in a position slightly inclined from the horizontal. As they revolve the salt passes from one end to the other and is separated into the various sizes.

STORING, PACKING AND SHIPPING.

The stock house is a large room traversed by runways near the roof which cuts it up into small squares or rectangles. The salt is transported from the evaporators in carts to the desired portion of the stock house and dumped from the runway onto the floor below. Here it is allowed to age, at least twenty days being required by the state inspection law, and is then ready for shipping.

The crude salt is shipped in bulk, barrels, and sacks, both by rail and by boat. When shipped in bulk, the salt is taken from the stock house floor, loaded into carts, and after having been weighed is wheeled to a belt elevator which carries it up to a chute which conveys it into the car or boat. Plate VB shows a boat loading bulk salt at the No. 1 plant of the Louis Sands Salt and Lumber Co., Manistee.

When packed in barrels, the packing is done by hand and 280 pounds constitute a barrel. Some plants manufacture their own barrels, others buy them from the manufacturers. The vacuum salt being more hygroscopic than the grainer salt packs much harder. It is therefore often necessary to use dynamite to loosen it before it can be shoveled

into the barrels. Furthermore this packing permits the use of a barrel only two-thirds the size of that required for the grainer salt. After packing, the barrels are loaded on a truck and wheeled into a car or onto the dock as the case may be.

Of the crude salt, only the packers is shipped in sacks. These sacks are made of gunny cloth and hold 56 pounds. Table and dairy salt is packed for the most part in white cloth bags of various sizes. These sacks are filled by automatic sackers and the smaller ones are sewed by machinery, the larger ones being sewed by hand. Some companies also use pasteboard cartons for small packages of table salt.

CHAPTER V.

THE PRODUCT.

The product of the early years of manufacture failed in competition with salt from other states owing to a lack of uniformity. To improve these conditions, local inspection was early adopted by some of the manufacturers, and in 1869, the state inspection law was passed. This law as amended in 1873, 1875, 1877, 1879, 1883, 1887, 1899, 1903, and 1905 is given in Appendix B. The office of State Salt Inspector was abolished by the legislature of 1913.

CHARACTER OF THE PRODUCT.

As may be seen from the following analyses of crude salt the product of the Saginaw valley differs from that of the other districts generally in possessing a lower content of calcium sulphate. This salt is therefore less liable to cake so hard. It does however contain a larger percentage of calcium chloride and magnesium chloride and is therefore more hygroscopic. Up to the present time, the Saginaw valley product has not been successfully used in the manufacture of table salt.

93. East Saginaw Salt Manufacturing Co., East Saginaw, Mich. Kettle salt. Analysis by Dr. C. A. Goessmann. (Geol. Sur. Mich., Vol. III, p. 194.)

94. Bay City Salt Co., Bay City, Mich. Pan salt. Analysis by S. S. Garrigues. (Geol. Sur. Mich., Vol. III, p. 194.)

95. Buffalo Salt Co., East Saginaw, Mich. Steam salt. Analysis by Dr. C. H. Hahn. (Geol. Sur. Mich., Vol. III, p. 195.)

96. North American Chemical Co., Bay City, Mich. Vacuum pan salt. Analysis by A. Llewelyn Allen. Furnished by Mr. M. L. Davies.

97. Filer and Sons, Filer City, Mich. Vacuum pan salt. Analysis by W. and H. Heim, Saginaw, Mich. 1888. Furnished by Mr. E. G. Filer.

98. Buckley and Douglas Lumber Co., Manistee, Mich. Vacuum pan salt. Analysis by Fred Ruschaupt and Son, Milwaukee, Wis. Feb. 14, 1910. Furnished by Mr. J. J. Hubbell.

99. Same. Grainer salt.

100. Louis Sands Salt and Lumber Co., Manistee, Mich. Grainer salt. Analysis by J. E. Siebel, Chicago, Ill. 1881. Furnished by Mr. T. B. Jones.

The composition of Michigan table salt is shown in Table XXV.

TABLE XXIV.

	93.	94.	95.	96.	97.	98.	99.	100.
Calcium sulphate.....	0.3165	0.697	0.478	0.2	0.7685	1.354	1.436	1.573
Calcium chloride.....	0.3564	0.329	0.365	0.8	0.148			0.231
Calcium carbonate.....								0.016
Magnesium chloride.....	0.1408	0.340	0.694	0.3		0.021	0.047	0.197
Sodium sulphate.....						0.208	0.283	
Sodium chloride.....	95.8422	97.286	94.366	93.5	99.0835	97.183	96.591	95.748
Ferrous carbonate.....								0.004
Ferric oxide and alumina.....						0.172	0.158	
Silica.....								0.207
Organic matter.....								0.006
Moisture.....	3.3441	1.346	3.478	5.2		0.432	1.485	2.218
Total.....	100.0000	100.0000	100.000	100.00	100.0000	100.000	100.000	100.000

The values are given in percentages.

TABLE XXV.

	101.	102.	103.	104.	105.	106.	107.
Sodium chloride.....	99.334	99.313	99.391	98.86	98.55	98.23	98.30
Calcium sulphate.....	0.495	0.600	0.560	0.98	0.61	0.49	0.57
Calcium chloride.....	0.102	.....	absent	.....	0.25	0.41	0.47
Magnesium chloride.....	absent	absent	absent	trace	0.11	0.045	.....
Water at 100° C.....	0.040	0.076	0.049	0.16	0.47	0.82	0.65
Insol. in water.....	0.029	0.012	trace	0.003	0.01	0.005	0.007
Total.....	100.000	100.000	100.000	100.103	99.40	100.000	99.997

101. Delray Salt Co., Delray, Mich. P. S. Brand, table and dairy salt. Analysis by Prof. F. S. Kedzie, Sept. 5, 1908, who states, "The sample contains no magnesium salts." Furnished by Mr. Jos. P. Tracy.

102. Same. Delray Table Salt. Analysis by Prof. F. S. Kedzie, Jan. 28, 1909, who states, "Practically free from calcium chloride as I found but 1-1000 of 1% of this substance in the sample tested." "The sample contained no salts of magnesia." Furnished by Mr. Jos. P. Tracy.

103. Same. Analysis by H. Spurrier, Feb. 6, 1910. Furnished by Mr. Jos. P. Tracy.

104. Port Huron Salt Co., Port Huron, Mich. Analysis by the Michigan Technical Laboratory, Detroit, Mich., June 4, 1910. Analysis furnished by Mr. Otto Huette.

105. Same. Analyst, unknown. Furnished by Mr. Otto Huette.

106. Michigan Salt Co., Marine City, Mich. Cadillac Brand, table salt. Analysis by Robt. E. Devine, 301 Park Bldg., Detroit, Mich., June 30, 1910. Furnished by Mr. Sidney C. McLouth.

107. Same.

Rock salt is produced in Michigan only at the shaft of the Detroit Salt Co., Oakwood. An analysis of their product, as given by J. W. Turrentine,² is as follows:

Potassium chloride.....	108. trace.
Sodium chloride.....	97.3
Calcium chloride.....	trace.
Magnesium chloride.....	1.2
Sodium sulphate.....	1.5
Calcium sulphate.....	trace.
Total.....	100.000

108. Detroit Salt Co. Sample from roof to floor at working face. Representative of stratum being removed. 1911. R. F. Gardner, analyst.

PRODUCTION.

The development of its salt industry was so rapid that, in 1876, after only sixteen years of production, Michigan became the leading producer

²Turrentine, J. W. Jour. Ind. and Eng. Chem., Vol. 4, No. 11, p. 831.

of salt in the United States. This position it held until 1893, when New York assumed first place. In 1901, Michigan again acquired the leadership, only to yield it once more to New York in 1902. However, in 1905, Michigan passed its rival for the third time and has since then^a maintained the first rank by a considerable margin.

The annual production of salt in Michigan, from the foundation of the industry to 1910, as reported by the state salt inspector, is given in Table XXVI, column 3. Since these figures represent inspection rather than absolute production, they are only approximate. In column 4, the figures as given in Mineral Resources, U. S. G. S. are shown. From 1893 on these statistics were obtained directly from the manufacturers and therefore represent the true annual production. They also include the salt in the brine used in the manufacture of soda ash, etc., or what is known as "brine salt." While this salt is not produced in the solid form, yet it should properly be considered as part of the saline wealth of the state. The large discrepancy between the production as given by the state salt inspector and that given by the United States Geological Survey is due to the inclusion of the brine salt by the latter.

Column 2 represents the total production of the United States, and Column 5, Michigan's percentage of the total, based on the data given by the United States Geological Survey. From this it will be seen that, since 1880, Michigan has never produced much less than one-quarter, with a number of years approaching one-half, and an average of nearly two-fifths of the entire production.

This table shows that, with one or two exceptions, the growth of the industry in Michigan was steady up to 1887. Then for a period of about six years the production remained practically stationary. This was due in part to a drop in prices and also to the competition from new districts. The big increase of nearly one million barrels, in 1893, is more apparent than real and was due to a change in the method of obtaining the statistics. The decrease recorded in the inspection for 1894 was undoubtedly due to the tariff act of that year, which placed salt on the free list. The competition of the imported salt with the eastern salt forced it to seek a new outlet which brought it into closer competition with the western salt. By the tariff act of 1897, a duty was again placed on salt. The results of this are reflected in the increased production of 1898, as shown by the increased inspection. The still greater production recorded by the United States Geological Survey was due to the development of the soda ash industry in Wayne county. The sudden and enormous decrease of over three million barrels, in 1903, was due in part to the closing down of a large number of plants as a result of the great drop in price the preceding year, which

^aTo 1910.

resulted in a decrease in manufacture of nearly a million barrels. The balance represents the decrease in brine salt. Although there was a decreased inspection in 1909, the salt inspector's report shows that there was an increase in production of over four hundred thousand barrels, in spite of the fact that a number of plants were closed down.

TABLE XXVI.

Year.	U. S. Production.	Michigan Production.		Per cent. of total.	Value.	Price.
		Salt Inspector.	U. S. G. S.			
1860.		4,000				
1861.		125,000				
1862.		243,000				
1863.		466,000				
1864.		529,072				
1865.		477,200				
1866.		407,997			\$734,395	\$1.80
1867.		474,721			840,255	1.77
1868.		555,690			1,028,027	1.85
1869.		561,288			786,835	1.58
1870.		621,352			820,185	1.32
1871.		728,175			1,063,135	1.46
1872.		724,481			1,057,742	1.46
1873.		823,346			1,127,984	1.37
1874.		1,026,970			1,220,094	1.19
1875.		1,081,856			1,190,042	1.10
1876.		1,482,729			1,556,865	1.05
1877.		1,660,997			1,411,847	0.85
1878.		1,855,884			1,577,501	0.85
1879.		2,058,040			2,099,200	1.02
1880.	5,961,060	2,676,588	2,485,177	41.69	2,271,931	0.75
1881.	6,200,000	2,750,299		44.35	2,418,171	0.85
1882.	6,412,373	3,037,317	3,037,317	47.36	2,126,122	0.70
1883.	6,192,231	2,894,672	2,894,672	46.74	2,344,684	0.81
1884.	6,514,937	3,161,806	3,161,806	48.53	2,392,648	0.757
1885.	7,038,653	3,297,403	3,297,403	46.84	2,967,663	0.900
1886.	7,707,081	3,667,257	3,667,257	47.58	2,426,989	0.661
1887.	8,003,962	3,944,309	3,944,309	49.17	2,291,842	0.581
1888.	8,055,881	3,866,228	3,866,228	47.99	2,261,743	0.585
1889.	8,005,565	3,846,979	3,856,929	48.17	2,088,909	0.541
1890.	8,776,991	3,838,637	3,837,632	43.72	2,302,579	0.600
1891.	9,987,945	3,927,674	3,966,784	39.52	2,037,289	0.513
1892.	11,698,890	3,812,504	3,829,478	32.81	2,046,963	0.523
1893.	11,897,208	3,514,485	3,057,898	25.70	888,837	0.287
1894.	12,968,417	3,138,941	3,341,425	26.53	1,243,619	0.375
1895.	13,669,649	3,529,362	3,343,395	24.46	1,048,251	0.315
1896.	13,850,726	3,336,242	3,164,238	22.89	718,408	0.229
1897.	15,973,202	3,622,764	3,993,225	24.99	1,213,619	0.313
1898.	17,612,634	4,171,916	5,263,564	29.88	1,628,081	0.311
1899.	19,708,614	4,732,669	7,117,382	36.14	2,205,924	0.309
1900.	20,869,342	4,738,085	7,210,621	34.55	2,033,731	0.282
1901.	20,566,661	5,580,101	7,729,641	37.58	2,437,677	0.328
1902.	23,849,231	4,994,245	8,131,781	34.10	1,535,823	0.188
1903.	18,968,089	4,387,982	4,297,542	22.65	1,119,984	0.260
1904.	22,030,002	5,390,812	5,425,904	24.62	1,579,206	0.309
1905.	25,966,122	5,671,253	9,492,173	35.24	1,851,332	0.196
1906.	28,172,380	5,644,559	9,936,802	36.31	2,018,760	0.203
1907.	29,704,128	6,298,463	10,786,630	35.39	2,231,129	0.208
1908.	28,822,062	6,247,073	10,194,279	35.34	2,458,303	0.241
1909.	30,107,646	6,055,661	9,966,744	33.10	2,732,556	0.274
1910.	30,305,656	5,597,276	9,452,022	31.18	2,231,262	0.236

The annual inspection of salt, since the adoption of the state inspection law, according to grades, is given in Tables XXVII and XXVIII. Previous to 1898, table salt was included under "fine." The figures given under "table" in Table XXVIII include all fancy grades.

TABLE XXVII.

Year.	Fine.	Packers.	Solar.	Second quality.	Common coarse.
	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.
1869.....	513,989	12,918	15,264	19,117	.....
1870.....	568,326	17,869	15,507	19,650	.....
1871.....	655,923	14,677	37,675	19,930	.....
1872.....	672,034	11,110	21,461	19,876	.....
1873.....	746,762	23,671	32,267	20,706	.....
1874.....	960,757	20,090	29,391	16,741	.....
1875.....	1,027,886	10,233	24,336	19,410	.....
1876.....	1,402,410	14,233	24,418	21,668	.....
1877.....	1,590,841	20,389	22,949	26,818	.....
1878.....	1,770,361	19,367	33,541	32,615	.....
1879.....	1,997,350	15,641	18,020	27,029	.....
1880.....	2,598,037	16,691	22,237	48,623	.....
1881.....	2,673,910	13,885	9,683	52,821	.....
1882.....	2,928,542	17,208	31,335	60,222	.....
1883.....	2,828,987	15,424	16,735	33,526	.....
1884.....	3,087,033	19,308	16,957	38,508	.....
1885.....	3,230,646	15,480	19,849	31,428	.....
1886.....	3,548,731	22,221	31,177	71,235	3,893
1887.....	3,819,738	19,385	13,903	73,905	17,378
1888.....	3,720,319	18,126	26,174	87,694	13,915
1889.....	3,721,099	19,780	17,617	93,455	4,987
1890.....	3,655,331	20,337	18,896	143,068	.....
1891.....	3,764,108	11,400	17,335	121,269	13,559
1892.....	.....	.....	.....	.....	.....
1893.....	3,421,607	16,550	11,893	64,435	.....
1894.....	3,072,241	14,944	7,744	44,012	.....
1895.....	3,421,796	15,350	39,907	52,309	.....
1896.....	3,262,699	14,895	28,869	29,779	.....
1897.....	3,568,833	13,973	5,644	34,314	.....

TABLE XXVIII.

Year.	Medium.	Granulated.	Packers.	Solar.	Table.	Second quality.
	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.
1898.....	2,702,312	1,199,553	14,649	.....	198,002	43,178
1899.....	2,706,430	1,744,961	29,892	17,353	189,107	44,922
1900.....	2,789,982	1,680,614	26,759	24,238	162,590	53,902
1901.....	3,361,616	1,895,093	39,490	11,523	168,068	84,311
1902.....	3,065,417	1,604,180	71,858	.....	219,016	133,774
1903.....	2,601,932	1,459,029	92,316	8,571	281,514	44,600
1904.....	3,120,647	1,775,148	95,424	12,535	360,533	36,525
1905.....	.....	.....	.....	.....	.....	.....
1906.....	2,977,518	1,988,759	120,658	7,200	520,313	30,111
1907.....	3,230,561	2,227,137	137,567	7,414	655,436	39,140
1908.....	3,309,365	2,192,486	119,454	.....	575,681	50,770
1909.....	2,871,274	2,354,035	118,184	.....	650,138	62,030
1910.....	2,702,372	1,910,680	112,561	.....	779,756	91,907

VALUE OF THE PRODUCT.

The total value of the product and the average net price per barrel are given in columns 6 and 7 of Table XXVI. Previous to 1880, the value has been calculated from the average price as given by the United States Geological Survey, and from that time to date, the price has been determined from the total value. It should be pointed out that the values given for 1893 and following years represent the actual value of the salt itself, whereas, before that date, the cost of the package is included. This not only explains the apparently great drop in price in 1893, but also gives fictitious values for the preceding years. If we allow twenty cents as the cost of the barrel (this is probably somewhat below the present cost), we see that the price per barrel has decreased from \$1.65 per barrel in 1868 to \$0.188 in 1902, with an average for the ten years (1901-10) of \$0.244. The above figures are the average for all grades. Table XXIX gives the production for the five years, 1906-10, classified as to grades with the corresponding values. From this it may be seen, that while table salt has commanded for 1910 an average net price of \$0.708 per barrel, brine salt was worth but \$0.051; common fine, \$0.331; common coarse, \$0.349; and packers, \$0.475 per barrel.

TABLE XXIX.⁴

Year.	Table and dairy.		Common fine.		Common coarse.	Packers.	Brine and other.	Total.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1906.....	Barrels. 509,905	Dollars. 362,368	Barrels. 2,927,478	Dollars. 757,470	Barrels. 2,021,287	Dollars. 618,727	Barrels. 91,089	Dollars. 33,733
1907.....	657,509	392,641	3,901,270	914,154	1,743,840	471,378	4,387,043	246,462
1908.....	584,452	620,647	3,454,062	963,617	2,029,956	610,286	4,664,552	235,729
1909.....	585,370	732,907	3,530,303	1,125,095	2,103,719	647,878	3,991,083	205,084
1910.....	798,434	565,653	2,216,181	734,823	1,992,465	596,301	3,648,395	185,051
							4,104,934	211,317
							9,452,022	2,231,262
							9,936,802	2,018,760
							10,786,630	2,062,357
							10,194,279	2,458,303
							9,966,744	2,732,556

⁴Compiled from U. S. G. S. Mineral Resources.



Figure 32. Map showing producing salt districts of Michigan.
 Circles represent present producing districts.
 Crossed circles represent former producing districts.

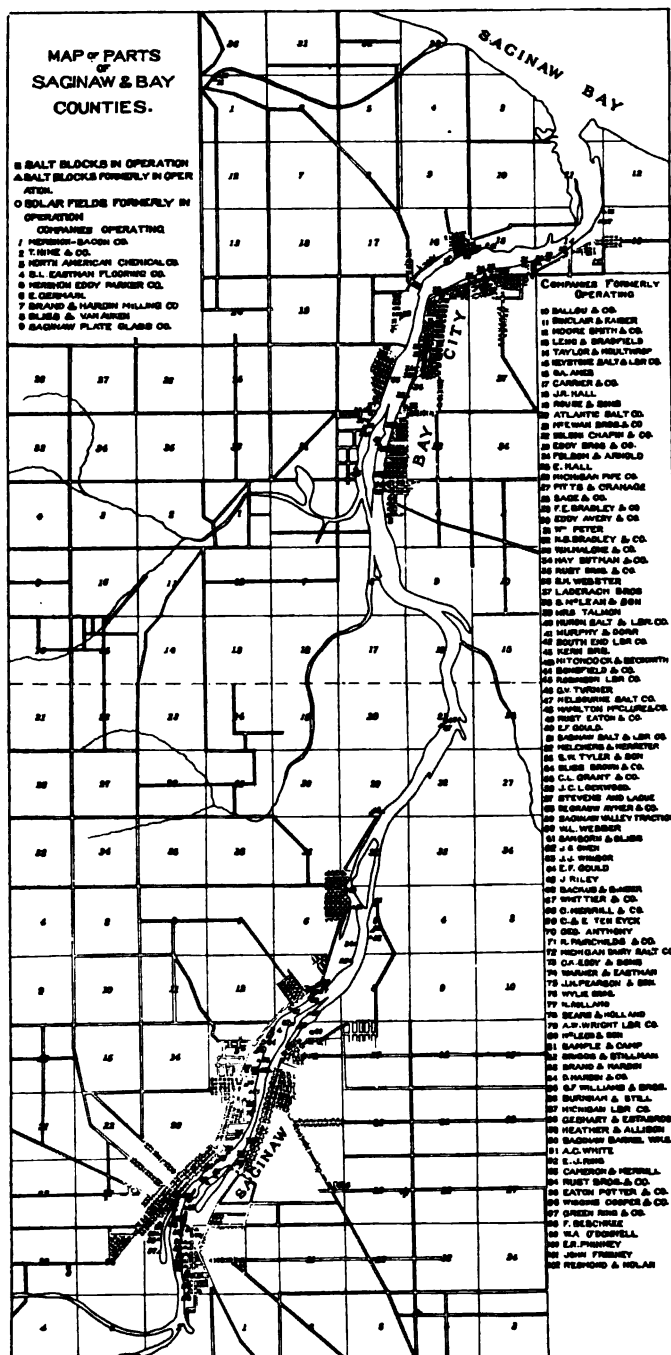


Figure 33. Map of parts of Saginaw and Bay counties.

CHAPTER VI.

THE INDUSTRY BY DISTRICTS.

For purposes of discussion, it has seemed advisable to limit the various districts to be discussed by county lines. Neglecting the early unsuccessful attempts to manufacture salt, as at Grand Rapids, the industry in the various counties will be taken up in chronological order. The general location of plants, both those which are producing and those which have been in operation in the past, is shown in Fig. 32.

SAGINAW COUNTY.

From the first production of salt in 1860 by the East Saginaw Salt Manufacturing Co., the industry grew very rapidly. Plants were established along both sides of the Saginaw river; at Salina and East Saginaw on the east side, and at Saginaw City, Florence, Carrolton, Zilwaukee, and Melbourne on the west side. In addition to these plants, salt blocks were built at Bridgeport and along the Cass River, at Buena Vista, Paines, Garfield, and later at St. Charles. All of the blocks at which salt is or has been manufactured are shown, as far as their location could be learned, in Fig. 33.

The manufacture of salt in the Saginaw valley has been and still is essentially a by-product industry. In the early days of the kettle and pan blocks, the refuse from the saw mills was used as fuel in evaporating the brine. When later the grainer process, the only one now employed in this district, was instituted, the slabs and sawdust were used to make steam for the saw mills and the exhaust steam was used in the grainers. More recently salt blocks have been operated in connection with industries other than lumber. Thus the Saginaw Plate Glass Co. utilizes its exhaust steam in the manufacture of salt, the Germaine block is run in connection with the Germaine Piano Co., and the Saginaw Salt Co., St. Charles, secures its steam from the Robt. Gage Coal Co. The decline of the salt industry in this county seems to have been correlative with the passing of the lumber, so that now but seven plants are in operation where once there were ten times as many.

Two brines have been used in the manufacture of salt, the Parma and the Napoleon. The latter, on account of its greater concentration, has been the more largely used and is the only one employed at the present time. This brine, the composition of which is shown by the analyses given, is found at a depth of about 650 to 820 feet.

The characteristic geological section of this district may be seen from

the record of the No. 4 well of the Saginaw Plate Glass Co.,¹ which also contains references to other wells in that vicinity.

Saginaw Plate Glass Co., Well No. 4, 600 A. T. Near the S. E. cor. Sec. 33. T. 12 N., R. 4 W.

	Thickness.	Total depth.
Pleistocene.		
Fine sand, Algonquin beach (4 mm.)	5	5
Plastic red clay	20	25
Like that at Paines, lacustrine, calcareous.		
Clay, blue.	53	78
Bottom 6 feet "putty." All calcareous.		
Gravel with water	2	80
Till "hardpan" with coal	21	101
106 ft. in No. 1.		
8" casing 111 ft. in No. 2.		
122 ft. in No. 3.		
Saginaw formation.		
Dark shale, Lower Verne coal horizon? "Bastard"	14	115
Light (fire clay) and dark shale.	7	122
Blue shale.	17	139
Black shale.	15	154
Coal, large Saginaw seam? or Middle Rider.	7	161
Water Sp. Gr. 1.000.		
White shale with black impressions	4	165
"Fire clay"		
Dark shale. Saginaw coal horizon?	8	173
Blue shale with some hard seams.	5	178
White shale and brittle blue shale	1	178.5
(probably some sediment).		
Dark gray shale.	19.5	198
Very dirty shale.	13	211
Coal horizon? Lower rider? Water Sp. Gr. 1.005.		
Dark shale.	9	220
Gray shale.	79	299
Water at 280, Sp. Gr. 1.005.		
Shale, part dark, part "fire clay" light	9	308
Lower coal horizon?		
Shales with nodules or bands of siderite.	56	364
Very dark shale, coal horizon? Bangor Rider.	12	376
Water at 375 Sp. Gr. 1.006.		
Blue shale.	19	395
Micaceous sandstone.	9	404
Very dark shale; almost coal.	21	425
Near 410-425 coal horizon. Bangor coal?		
Dark shale.	49	474
Water at 476 Sp. Gr. 1.016. Much gypsum.		
Parma Conglomerate and Sandstone.		
Transition sandstone, fine grained.	24	498
Sand rock.	23	521
Conglomeratic sandstone.	14	535
Two samples missing, 535-583. I think they were Bayport limestone. Top beds at 476 contain some petroleum "gum" inspissated in a cavity. There was a ten inch drop of the tools. The base samples are full of split white quartz pebbles. In No. 2 this stratum is said to come at 520 to 555. In No. 7 this stratum is said to come at 485.		
Compare at East Saginaw 292.5-399; Litchfield, Carrolton, 302-411; Ketchum well 310-430; Gallagher 345-482; Southerland 341-408.		
Bayport or Maxville Limestone.		
Top at.	535?	or 583
Limestone.	81	616
Water at 561 ft. Sp. Gr. 1.012.		
Note that the water was fresher than at the top of the Parma. There was probably much erosion just above this, and the division between it and the Parma is irregular. In No. 2 it is from 555 to 625. Temperature 56° at 630 ft. by thermometer 9101, March 23, 1906.		
Michigan Series.		
Black and dark shale.	35	651
Gypsum.	25	676
Near margin of this basin at this time?		
Compare No. 2 gypsiferous shales to 717.		
Dolomite.	12	688

¹Geol. Sur. Mich., Ann. Rpt., 1908, p. 102. Corrections have been made in the figures for the thickness of the strata at 154-161 and 474-498. The two samples reported as missing at 535-583 show the sample from 535 to 561 to be a sandy limestone somewhat stained with limonite and from 561 to 583, a hard limestone with a slight clay odor.

	Thickness.	Total depth.
Alma 696.		
Blue shale.....	58	746
With lime and gypsum at the top, sandy 735-743.		
Alma 905-945.		
Water at 620 Sp. Gr. 1.024.		
Note the doubling of salinity on striking the Michigan. Casing to keep out the gypsum goes to 698 feet. This second casing to cut off the gypsum somewhat over 600 feet deep is noticeable in all the wells.		
Gray limestone.....	5	751
Dark gray shale.....	9	760
Gray limestone.....	14	774
Water at 775 ft. Sp. Gr. 1.1207; more salt, less gypsum.		
Blue limestone.....	21	795
Sandy shale.....	14	809
In No. 7, 3 ft. of red shale at 785 ft.		
Dolomite.....	11	820
Base in No. 6 at 812 ft. In No. 7 at 822 ft. In No. 2 from 717 to 822 ft., is dolomitic limestone.		
Upper Marshall (Napoleon) sandstone.		
In No. 7 at 887. In No. 2 at 913.	78	898
Water at 27.5°C. has Sp. Gr. 1.193. By Salinometer 83° to 94°.		
Lower Marshall.		
Red clay.....	2	900
5 ft. in No. 7 to 892; 3 ft. in No. 6, in No. 1 at 906 ft. In No. 3, 500 ft. West there is said to be more lime in the sand rock.		

On account of the large amount of impurities in the brine possessing a greater solubility than the sodium chloride, a bittern is formed after the evaporation process has been carried on for some time. It is therefore necessary to remove the bittern from the grainer and replace it with fresh brine. These bitters are and have been for the most part thrown away. They have, however, been used in the manufacture of by-products. Until recently the only product obtained from the bitters was the bromine. The method employed consists, briefly, in treating the mother liquor with sulphuric acid and potassium chlorate in a stone still and distilling off the bromine into an earthenware receiver. The only stills now used in this district are at the plants of the Saginaw Salt Co., and they were not in operation at the time of visitation. Recently the Saginaw Plate Glass Co., has installed a plant for the recovery of the calcium chloride (Plate IIIA). The process consists of evaporating the mother liquors with steam under pressure until a certain consistency is obtained and the product is then run into iron drums, sealed, and allowed to solidify.

It has been found impossible to obtain complete statistics of production from this district, but the data given in Table XXX affords a general idea of the rise and fall of the industry.

TABLE XXX.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1875.....	461,902	1887.....	1,115,169	1899.....	424,432
1876.....	590,976	1888.....	1,050,265	1900.....	418,053
1877.....	674,641	1889.....		1901.....	557,138
1878.....		1890.....	1,006,854	1902.....	331,250
1879.....		1891.....	962,954	1903.....	179,533
1880.....	1,148,644	1892.....	842,235	1904.....	187,285
1881.....	1,083,990	1893.....	640,837	1905.....	156,978
1882.....	1,287,273	1894.....	462,983	1906.....	143,502
1883.....	1,185,957	1895.....	479,887	1907.....	328,083
1884.....	1,245,912	1896.....	428,493	1908.....	337,161
1885.....	1,178,910	1897.....	284,337	1909.....	344,729
1886.....	1,213,764	1898.....	424,044	1910.....	357,576

Companies.

Saginaw Plate Glass Co. (Plates III and IVA), Saginaw, Mich. Incorporated Dec. 1909. Capital stock, \$500,000.00. President, W. J. Wicks; vice president, A. D. Eddy; secretary-treasurer, Geo. C. Eastwood.

The plant consists of fourteen grainers (150'x12'x18" sloping to 21"), ten of which are run on exhaust steam and make medium salt, and four utilize the tail water from the others and make packers salt. The grainers are constructed of cement and those making medium salt are equipped with reciprocating rakers. The brine is obtained from ten wells ranging in depth from 892 to 917 feet. The brine is pumped with walking-beam pumps and stored in cisterns of which there are six (150'x20'x7'). Before passing into the grainers the brine is settled at a temperature of 175°F. to 180°F. There are three settlers (150'x12'x4'), (150'x12'x32'), and (150'x12'x6'). Exhaust steam from the glass works is used in evaporating the brine. The capacity of the plant is 1,000 barrels per day. Medium and packers grades are manufactured, and the product shipped by rail in barrels, sacks, and bulk, is sold through the Michigan Salt Association. Fifteen men are employed in operating the plant.

Brand and Hardin Milling Co., Saginaw, Mich. Incorporated, June 16, 1908. Capital stock, \$50,000.00. President, J. F. Brand; vice president, C. H. Brand; secretary-treasurer, W. E. Dewitt.

The equipment consists of two wooden grainers (120'x10'x22"), three cisterns (20'x30'x6'), and one settler (120'x8'x6'). The brine is supplied by one well about 800 feet deep, the pumping being done with a walking-beam pump. The plant is operated with live steam and coal is used for fuel. The capacity is 100 barrels per day and six men are employed. The product is shipped in barrels entirely by rail. At the time of visitation the plant was not in operation.

Mershon Eddy Parker Co., Mershon, Mich. Re-incorporated, February, 1909. Capital stock, \$500,000.00. President, F. E. Parker; vice president, C. A. Eddy; secretary-treasurer, A. H. Hempstead.

The salt block of this company is run in connection with and utilizes the exhaust steam from the planing mill and box factory. It consists of four wooden grainers (110'x12'x18") which make medium salt and are lifted by hand every forty-eight hours. The brine is supplied by two wells that were put down thirty to thirty-five years ago and have an approximate depth of 700 feet. There are four cisterns (30'x20'x5') and two settlers (120'x8'x5'). Tail water is used to supply the heat for the settlers. The capacity of the plant is 150 barrels per day and it has storage facilities for 5500 barrels of bulk salt. Shipments are made entirely by rail and largely in barrels, the product being sold through the Michigan Salt Association. The operation of the plant requires the services of five men.

S. L. Eastman Flooring Co., Carrolton Township, Saginaw Co., Mich. Incorporated, January 1, 1904. Capital stock, \$80,000.00. President and treasurer, S. L. Eastman; secretary, W. H. Erwin.

This plant formerly the T. Jerome plant, is equipped with four wooden grainers, two of which are 7' 3"x115'x18" and two are 8'x110'x18". The salt is lifted by hand every forty-eight hours. Two wells, respectively 730 and 740 feet in depth are in operation. The thickness of the salt rock (that is the brine-bearing stratum) at this point is about 100 feet. Additional equipment consists of four cisterns (24'x24'x6') and two settlers (115'x7'x7' and 110'x10'x7'). The daily capacity is 100 barrels of medium salt. Both exhaust and live steam are used in the evaporation, but no coal is employed for fuel. The product is sold direct, mostly in barrels, and is shipped by rail. Number of men employed, six.

Bliss and VanAuken (Aaron T. Bliss and W. G. VanAuken), Saginaw, Mich. This plant consists of two wooden grainers (170'x10'x22"), equipped with automatic rakers, seven cisterns (80'x60'x5'), and one settler (170'x10'x5'). The brine is furnished by four wells ranging in depth from 800 to 1,008 feet, and the daily capacity is 100 barrels. The storage capacity is 12,000 barrels of bulk salt. Exhaust steam is obtained from the saw mill for evaporating the brine and the salt which is sold direct in barrels is shipped by rail. Six men are employed.

E. Germaine, Saginaw, Mich. The equipment consists of four wooden grainers (150'x12'x22") which are lifted by hand, five cisterns (30'x30'x6') and two settlers (150'x10'x5'). The brine is supplied by two wells having a depth of 725 feet. On the day the plant was visited, the brine registered 96° by the salinometer. Exhaust steam is used exclusively and is furnished by the planing mill and piano factory. Storage capacity is 8,400 barrels in bulk. Shipments are made entirely by rail and mostly in barrels. The number of men employed is six.

Saginaw Salt Co., St. Charles, Mich. Offices at Bay City, Mich.

Incorporated. Capital stock, \$50,000.00. President, Chas. Coryell; vice president, F. T. Woodworth; secretary-treasurer, F. W. Urch.

Plant No. 1 is operated in connection with the No. 1 shaft of the Robt. Gage Coal Co., and consists of five wooden grainers (150'x12'x30") with hand lift and four cisterns (24'x12'x6'). The two wells have a depth of about 850 feet. The daily capacity is 100-150 barrels as operated, and the storage capacity is 20,000 barrels in bulk. The plant is also equipped with a still for the recovery of bromine from the bitterns. Plant No. 2 which is located at shaft No. 2 is a duplicate of plant No. 1. The product is sold direct in bags, barrels, and bulk, and shipped by rail. Fifteen men are employed.

BAY COUNTY.

Soon after the initiation of the industry in Saginaw, it spread to Bay county and the Bay City Salt Manufacturing Co. started boring in June, 1860. The first production however was made by the Portsmouth Salt Manufacturing Co., which began boiling July 28, 1861, the former company beginning operations in October of the same year. From this time on, salt blocks were constructed rapidly on both sides of the Saginaw river from Salzburg to Saginaw Bay. Two small salt blocks were also erected in connection with saw mills at Kawkawlin. The location of these blocks as far as could be learned is shown in Fig. 33.

With regard to the development of the mechanical side of the industry, its history is practically that of Saginaw county except that it has perhaps gone a step further in that we find here the vacuum pan in operation. As in Saginaw county, the manufacture of salt in this district is and always has been a by-product industry. At the present time the three blocks remaining in operation use exhaust steam; two of them being operated in connection with saw mills and the third, that of the North American Chemical Co., utilizes the exhaust from the chemical works.

Strictly speaking but two brines (the Parma and the Napoleon) have been employed as a source of the salt, although the deep well of the North American Chemical Co., the record of which is reproduced from the Geological Survey of Michigan, Annual Report for 1905; as well as the one sunk on the property of Pitts and Cranage, pierced the Berea. At the present time, with the exception of the small amount of Berea brine from the North American Chemical Co.'s deep well, only the Napoleon brine is utilized. In addition to salt, the brine is used in the manufacture of sodium chlorate by the above named chemical company. The process consists in purifying the salt by recrystallization and then treating it electrolytically.

The Napoleon sandstone is here encountered at a somewhat greater

depth than at Saginaw and so we find that the wells put down to strike this sandstone vary from 830 to 850 feet in depth. The characteristic geological section of the district is shown in Fig. 34.

With the exception of one or two years the production since 1875 is shown in Table XXXI. This table shows that the maximum production was reached in 1882, when, after remaining stationary for a few years, it began a decline, which with the exception of a small re-

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The average flow in the wells is equivalent to about fifty barrels of salt per well per day. The pumping is done by walking-beam pumps operated by electricity, and the brine after treatment as indicated on a former page, is stored in seven cisterns (40'x30'x8'). From the cisterns the brine passes through a filter into the hot settlers of which there are six (90'x9'x7') and thence into the graniers. The daily capacity is 1,000 barrels and storage is provided for 100,000 barrels.

Mershon-Bacon Co., Bay City, Mich. Incorporated. Capital stock \$50,000.00. President, A. W. Bacon; vice president, E. C. Mershon; secretary-treasurer, W. B. Mershon.

This company, which is the successor of the Mershon Eddy Parker Co., Eddy Sheldon Co., etc., operates a small grainer block in connection with its saw mill. The block contains four wooden grainers (145'x12'x18") which are "lifted" by hand. The brine is supplied by three wells having a depth of approximately 1,000 feet, the pumping being done with walking-beam pumps. At the time the plant was visited, the strength of the brine was reported to have been falling off rapidly and considerable trouble was being experienced from gypsum.² The brine is stored in five cisterns (20'x20'x6') from whence it is drawn into the hot settlers of which there are two (145'x8'x6'). Only packers salt is manufactured and the daily capacity is 90 barrels. The storage capacity is about 9,000 barrels and the product is sold through the Michigan Salt Association. Shipments in bulk, barrels, and bags are made by rail. Five men are employed.

Theo. Hine and Co., Bay City, Mich. This company operates a small grainer block in connection with a planing mill. It contains two wooden grainers (150'x12'x18") which are "lifted" by hand. The brine is supplied by one well (the company has two wells but one is non-producing) and is stored in three cisterns (20'x30'x6'). Before entering the grainers the brine is preheated in two hot settlers (70'x12'x6'). The capacity is about 50 barrels per day.

HURON COUNTY.

The first salt well in Huron county was sunk by Ayres and Co., at Pt. Austin³ in 1863. Later a salt block was erected and the industry gradually spread to Caseville, Pt. Crescent, Grindstone City, New River (1874), Port Hope (1874), Harbor Beach (Sand Beach) (1876), and White Rock (1872). A block was also erected at Old Bayport but was never in operation. As in the Saginaw valley, the manufacture

²While the decrease in the strength of the brine might be due to an influx of fresh water through abandoned wells that have not been plugged, the increase in gypsum would seem to indicate that both difficulties are due to leaky casings which not only admit of an influx of fresh water but also of the Parma brine with its higher gypsum content.

³Lane, A. C., Geol. Sur. Mich., Vol. VII, Part II, p. 224.

of salt was associated very largely with the lumber industry and when the timber was removed and the saw mills closed down, the salt blocks disappeared, and in some instances the towns themselves, as for example Pt. Crescent and New River, no longer exist. Plate IVB shows the remains of the pan block of the Port Hope Salt Co. at Port Hope.

The brine employed in this district was obtained largely from the Berea sandstone which occurs at depths varying from 495-555 feet at White Rock, through 603-664 at Harbor Beach, 716-787 at Port Hope, 1,010-1,080 at Grindstone City and 1,160-1,225 at Port Austin, to 1,650-1,770 feet at Caseville. The composition of the brine is shown on a former page.

Complete statistics of production were not available but from Table XXXII a general idea of the magnitude, growth and decline of the industry may be obtained. No salt production has been reported from Huron county since 1896.

It was found to be rather difficult to locate definitely all of the wells of the various companies and even to determine the exact number of plants, as in some instances one plant was operated at different times by different companies and therefore all of the companies given in the state salt inspector's and other reports do not represent different salt blocks.

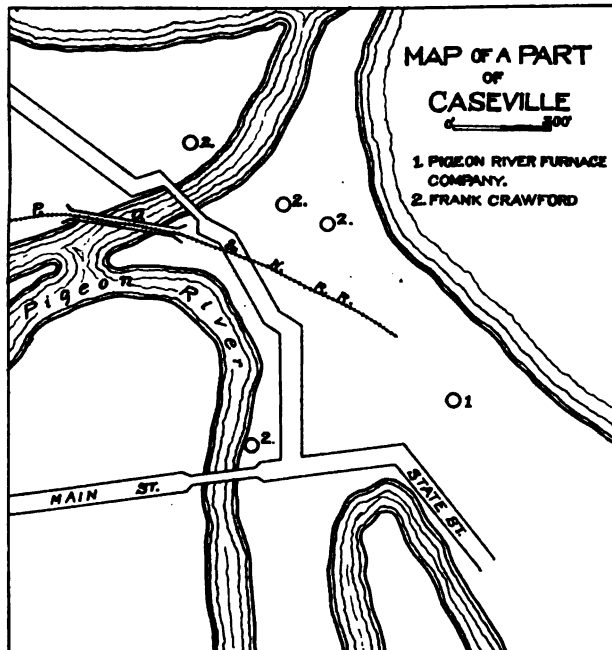


Figure 35. Showing location of salt wells at Caseville.

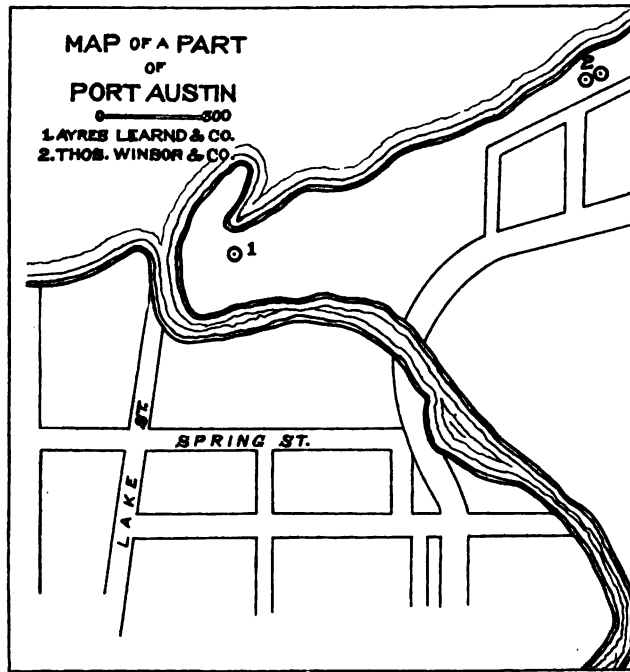


Figure 36. Showing location of salt wells at Port Austin.

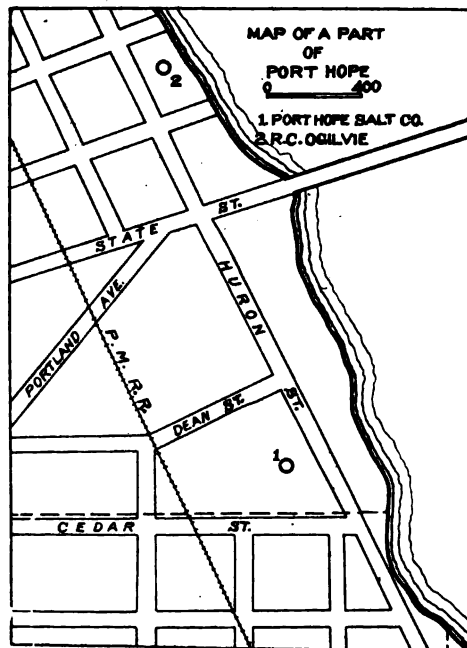


Figure 37. Showing the location of salt wells at Port Hope.

TABLE XXXII.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1870.....	15,296	1879.....		1888.....	163,200
1871.....		1880.....	256,841	1889.....	
1872.....		1881.....	326,852	1890.....	55,861
1873.....		1882.....	255,012	1891.....	47,407
1874.....		1883.....	256,965	1892.....	31,159
1875.....	102,526	1884.....	313,832	1893.....	19,040
1876.....	184,884	1885.....	306,664	1894.....	21,335
1877.....	239,213	1886.....	240,560	1895.....	24,860
1878.....		1887.....	176,582	1896.....	2,665

The location of most of the wells of the various companies are shown in Figs. 35, 36 and 37, and the following table is believed to represent the different blocks together with the companies operating them.

Location.	Block.	Companies.	Process.	Wells.	Depth.
Old Bayport.....	1	Tremain and Clark ⁴		1	2000 ⁵
Caseville.....	1	Frank Crawford.....	Pan.....	4	1760 — ⁶
		Caseville Salt Co.....			2290
	2	Frank Crawford.....	Steam.....		
		Curran Flack & Conley.....			
		Flack and Conley.....			
	3	Pigeon River Furnace Co.....	Steam.....	1	1760 ⁶
Pt. Crescent.....	1	N. B. Haskell.....			
		Haskell Razez & Co.....		1	1250
	2	Williamson Eaken & Co.....		1	
		Eaken & Soule.....			
		C. F. Soule.....			
		D. L. Davis.....			
Port Austin.....	1	Ayres Learned & Co.....	Pan.....	1	1284 ⁶
	2 (?)	Ayres & Co., (Skene well).....	Pan.....	1	1225 ⁷
	3	Thos. Winsor & Co.....	Pan.....	2	1300
		Port Austin Mfg. Co.....			
		R. W. Irwin.....			
		Razez & Irwin.....			
		R. Winsor & Son.....			
Grindstone City...	1	Worthington & Co.....	Steam ⁸	2	1080 ⁹
		Cleveland Stone Co.....			
New River.....	1	New River Salt Co.....	Pan.....	2	1029 ¹⁰
Port Hope.....	1	R. C. Ogilvie.....	Pan.....	1	
	2	Port Hope Salt Co.....	Pan.....	1	785 ¹¹
		W. R. Stafford.....			
Harbor Beach. (Sand Beach)...	1	Jenks & Co.....	Pan.....	2	702 ¹²
		Huron Dairy Salt Co.....	later Steam.....		900 1920
White Rock.....	1	Thomson & Bro.....	Pan.....	3	555 ¹³
		R. Winsor & Co.....			700 ¹³ 1311 ¹³

⁴Plant never operated.

⁵Lane, A. C., Geol. Sur. Mich., Vol. VII, Part II, p. 224.

⁶According to Mr. Wm. Johnson. 1198 feet according to Geol. Sur. Mich., Vol. V, Part II, p. 75.

⁷Geol. Sur. Mich., Vol. V, Part II, p. 76; Vol. VII, Part II, p. 224.

⁸Lane reports a pan block, Mr. Johnson a steam block.

⁹Geol. Sur. Mich., Vol. V, Part II, p. 62.

¹⁰For section see Geol. Sur. Mich., Vol. V, Part II, pp. 72-5.

¹¹Geol. Sur. Mich., Vol. V, Part II, p. 76; Vol. III, p. 201.

¹²Geol. Sur. Mich., Vol. V, Part II, pp. 80-2.

¹³Same, p. 86.

MACOMB COUNTY,¹⁴

In the late sixties, a well was put down at Mt. Clemens for oil. The well was sunk to a depth of 1,000-1,100 feet and although no oil was found, a strong brine was obtained and the well was taken over by Snook, Bush and Mosher, who erected a salt block and for several years produced a small amount of salt. (An attempt to obtain statistics of the production failed). The venture however proved unsuccessful owing to the fact that the well did not pierce the rock salt of the Salina, but stopped in the Monroe formation and the brine contained too high a percentage of bitterns to be satisfactory for the manufacture of salt.

While this salt project proved a failure, it resulted in the discovery of the curative properties of the mineral waters which have made Mt. Clemens one of the most noted of health resorts. There was employed at the salt block a man by the name of Kellogg who was afflicted with salt rheum. He had formerly lived near the ocean and had observed that the sea water benefited his ailment and so he asked permission to use some of the brine. His request was granted and he built himself a small bath house at the plant, in which he effected a cure. The brine was then investigated by Dr. Taylor, who had the brine drawn from the well to his house in a tank wagon and used it in treating some of his patients with such success that the fame of the waters spread and the industry grew rapidly. The composition of these waters may be seen from analyses 58-60.

IOSCO COUNTY.

The first salt block in Iosco county was erected by Grant and Son at East Tawas in 1872. Later blocks were erected at Tawas City, Oscoda

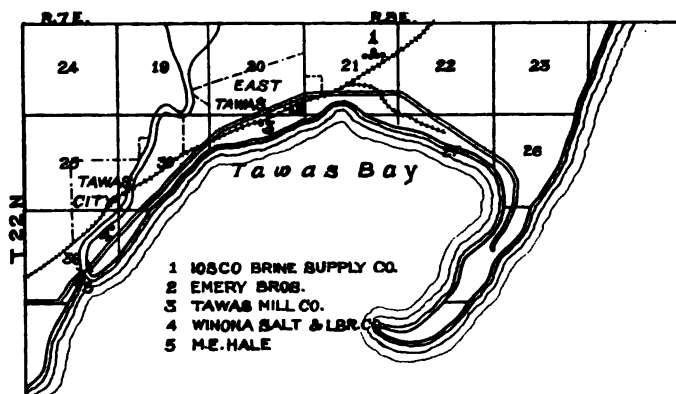


Figure 38. Sketch map showing location of wells at East Tawas.

¹⁴For the major portion of the data, the author is indebted to Mr. John R. Snook, Mt. Clemens, Mich.

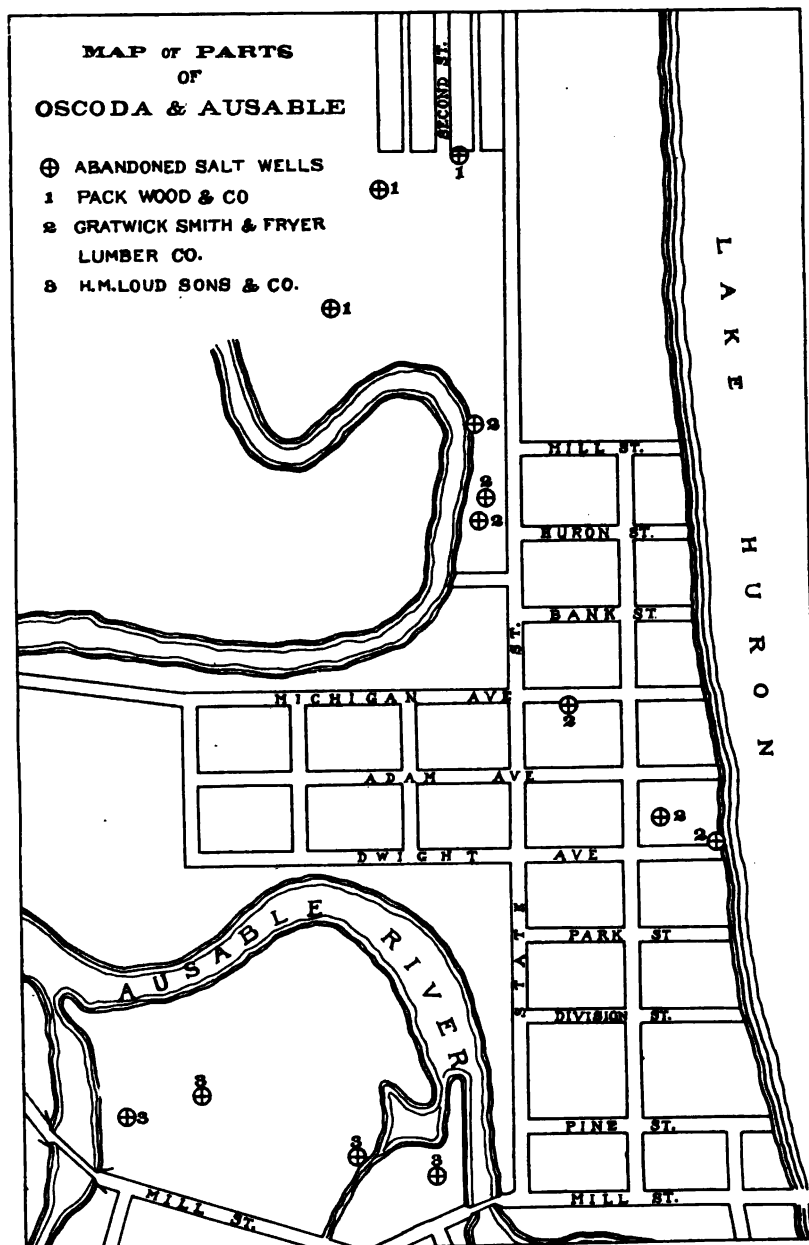


Figure 39. Showing the location of salt wells at Oscoda and AuSable.

and AuSable. According to Mr. William Elliott, the well driller, the first well at Oscoda was put down for Smith, Kelley and Dwight in 1875, two wells being drilled for Loud, Gay and Co., at AuSable the next year.

The brine employed was the Berea, which was obtained at a depth varying from approximately 835 feet at East Tawas to 1,200(?) feet at AuSable.

The production as far as data are available is shown in Table XXXIII. No production has been made since 1902 and about all that remains of the industry is shown in Plate VA. In addition to salt, bromine was also manufactured by Emery Bros., at East Tawas.

TABLE XXXIII.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1875.....	8,895	1885.....	236,543	1895.....	97,592
1876.....	29,592	1886.....	235,143	1896.....	129,715
1877.....	40,342	1887.....	309,008	1897.....	42,231
1878.....		1888.....	346,369	1898.....	58,359
1879.....		1889.....		1899.....	5,601
1880.....	147,800	1890.....	289,232	1900.....	28,847
1881.....	147,579	1891.....	239,365	1901.....	17,128
1882.....	211,667	1892.....	230,897	1902.....	3,045
1883.....	210,644	1893.....	157,228		
1884.....	224,687	1894.....	87,100		

The location of the various plants and wells as far as determinable is shown in Figs. 38 and 39, and the following table gives the various blocks, companies operating them and such other data as are available.

Location.	Block.	Companies.	Process.	Wells.	Depth.
Tawas City.....	1	A. M. McBain & Sons.....	Steam....	1	.....
	2	Winona Salt & Lumber Co.	Steam....	1	.....
East Tawas.....	1	Tawas Mill Co.....	Steam....	1	835 ¹⁵
	2	Weekes Bros.	Steam....	1	883 ¹⁶
	3	W. G. Grant and Son.....	Steam....	1	or 903
	3	Emery Bros.	Steam....	5	.....
Oscoda.....		G. P. and H. B. Smith.....	Steam....		.....
		Iosco Brine Supply Co.			.....
	1	Pack, Wood & Co.....	Steam....	7	.....
	2	Smith, Kelly and Dwight.....	Steam....	2	1070 ¹⁷ , 1103
AuSable.....		Smith, Gratwick & Co.....			.....
		Gratwick, Smith & Fryer Lumber Co.			.....
	1	Loud, Gay & Co.....	Steam....	4	1100- ¹⁸ 1200
	2	Oscoda Salt & Lumber Co. H. M. Loud & Sons L. Co. Potts Lumber Co.....	Steam....	0 ¹⁹	.....

¹⁵Geol. Sur. Mich., Vol. V, Part II, p. 57.

¹⁶Same, p. 75.

¹⁷According to Mr. Elliott bottom of sandstone is at 1060 in first well, sandstone, 60 feet thick. According to Wright (Geol. Sur. Mich., Vol. V, Part II, p. 75), 80 feet thick.

¹⁸Personal communication from Mr. Loud.

¹⁹Obtained brine from Iosco Brine Supply Co.

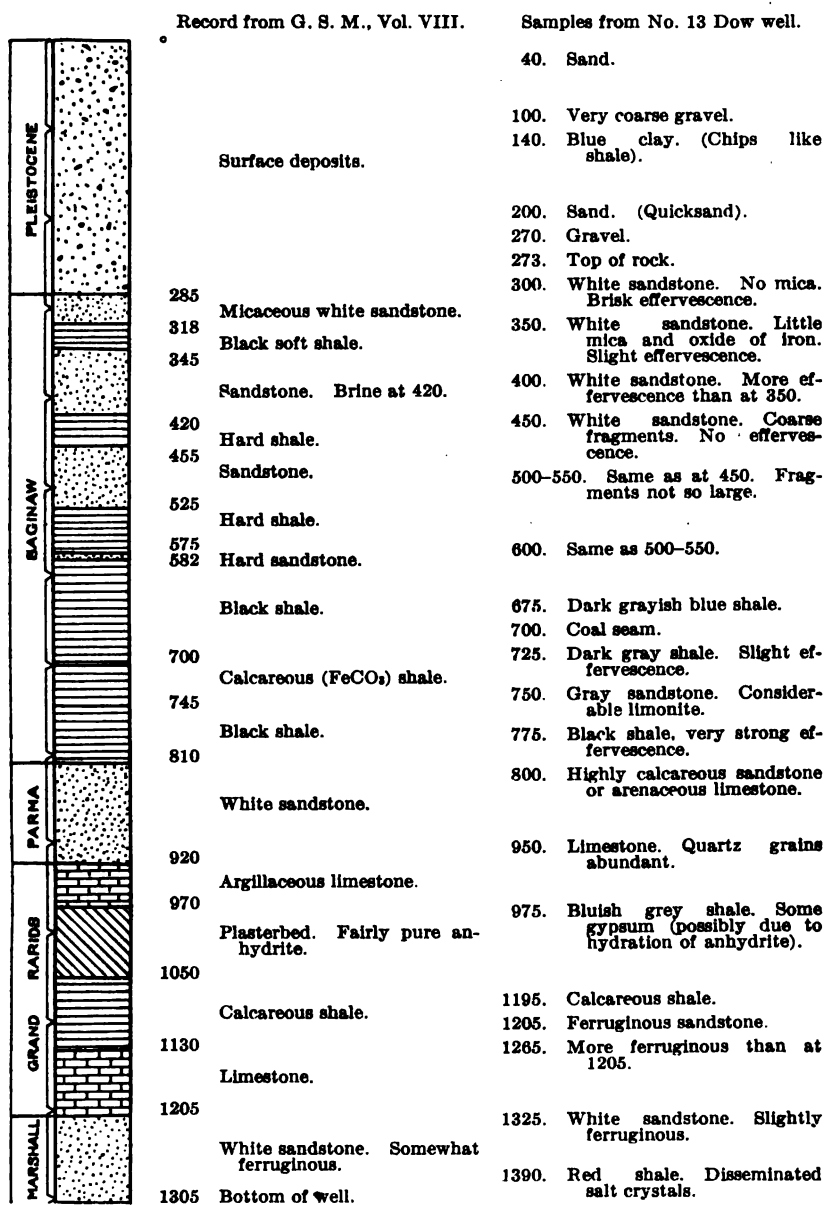


Figure 40. Section from record in Volume VIII, Michigan Geological Survey. Notes on samples from Well No. 13, Dow Chemical Company, Midland, Michigan, by C W. Cook.

MIDLAND COUNTY.

According to Mr. E. P. Rice, from whom the samples indicated in connection with the geological section shown in Fig. 40 were obtained. the first successful salt well in Midland county was put down at the

Larkin plant in 1878 or 1879. Following this a number of plants were erected and a small production was maintained until 1903. Of much greater importance however has been the production of bromine by the Dow Chemical Co., who are the largest producers of that product in the United States. In addition to bromine, they manufacture a large number of other chemicals, most of which are by-products. A partial list of their products is as follows:

Bromine.....	Tetrachlorethylene.
Chlorine.....	Hexchlorethane.
Bromides.....	Dichlormethane.
Bromates.....	Benzyl chloride.
Bleaching powder.....	Sodium benzoate.
Carbon tetrachloride.....	Benzoate of lead.
Sulphur chloride.....	Arsenate of lead.
Chloroform.....	Lime-sulphur wash.
Chloride of iron.....	Chloride of zinc.

The brine employed at Midland is that from the Napoleon sandstone (for analyses, see subject of Napoleon brines)²⁰ which occurs at an average depth of 1,245 feet and varies from 75 to 125 feet in thickness. A complete geological section prepared from the record as given by Lane (Geol. Sur. Mich., Vol. VIII, Part II, p. 163) compared with samples from the No. 13 well of the Dow Chemical Co., is shown in Fig. 40.

The production of salt for the district as far as data were obtainable is given in Table XXXIV.

TABLE XXXIV.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1880.....	41,462	1888.....	43,837	1896.....	24,358
1881.....	74,537	1889.....	.....	1897.....	34,056
1882.....	80,239	1890.....	49,609	1898.....	31,799
1883.....	66,135	1891.....	40,603	1899.....	26,700
1884.....	65,726	1892.....	33,380	1900.....	34,021
1885.....	62,710	1893.....	40,524	1901.....	26,664
1886.....	67,121	1894.....	29,458	1902.....	14,967
1887.....	41,256	1895.....	27,275		

The plants which have been operated in this county together with various data concerning them are given in the following table.

Location.	Block.	Companies.	Process.	Wells.	Depth.
Midland.....	1	Larkin and Patrick.....	Steam....	2	1300-1325 ²¹
		Chas. Brown.....			
	2	Wm. Patrick.....	Steam....	1	.....
		John Maloney.....			
	1 and 2	Midland Salt & Lumber Co.....			
	3	J. Herrick and Co.....	Steam....	2(?)	.....
		W. E. Cram.....			
	4	Samuel Foster.....	Steam....	1	.....
		Foster & McGill.....			
		Van Kleek & Co.....			
	5	Dow Chemical Co.....	(Do not make salt).	13	1305-1390

²⁰Mr. Dow states that the Midland brine is about equivalent to that at Saginaw boiled down two-thirds

²¹Geol. Sur. Mich., Vol. V, Part II, p. 69.



A. DAVIDSON-WONSEY COMPANY, MARINE CITY, MICHIGAN, SHOWING
SETTLING TANKS.



B. A HAND LIFT GRAINER, STEARNS NO. 2.



A. SAGINAW PLATE GLASS CO., SAGINAW, MICHIGAN. GLASS WORKS.



B SAGINAW PLATE GLASS CO., SAGINAW, MICHIGAN. GRAINIER
BLOCK.



A. SAGINAW PLATE GLASS CO., SAGINAW, MICHIGAN. CHEMICAL
WORKS.



B. RUINS OF PORT HOPE SALT CO., PORT HOPE, MICHIGAN.



A. SALT WELL AT EAST TAWAS, MICHIGAN.



B. STEAM BARGE LOADING BULK SALT AT THE NO. 1 PLANT OF THE
LOUIS SANDS SALT AND LUMBER CO.

GRATIOT COUNTY.

Salt was first manufactured in Gratiot county at St. Louis, in 1882, by T. E. Holcomb. The plant consisted of a small grainer block, the brine, that of the Napoleon sandstone, being supplied by three wells. A small production (see Table XXXV) was maintained for several years, the plant being operated in turn by T. E. Holcomb, H. T. Holcomb and A. T. Greenough. Later the wells were taken over by the St. Louis Chemical Co., and a plant erected to manufacture salt cake, sulphuric acid, hydrochloric acid, and bromides. The venture however did not prove a financial success and after changing hands several times the plant was finally closed. After having been considerably wrecked by a wind storm, the salvage was sold in 1910 at a receiver's sale for \$25,000.00.

TABLE XXXV.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1882.....	3,285	1884.....	3,500	1886.....	350
1883.....	6,186	1885.....	3,116	1887.....	2,069

MANISTEE COUNTY.

The beginning of the salt industry in Manistee county dates from September 10, 1881, when, according to Mr. Wm. Pehrson, the first lift of salt was made at the Rietz (now Sands No. 2) plant. The original well, which was begun in 1879, was put down for oil and gas and was started by a group of men of which Mr. Charles Rietz was the leading spirit. The funds were exhausted without any results having been attained and the well was taken over by Mr. Rietz who continued it on personal account. At a depth of 1,936 feet a salt bed 32 feet thick was encountered after an expenditure of about \$19,000.00. From this beginning the industry grew rapidly, plants being established near the mouth of the Manistee river and along both sides of Manistee Lake at Manistee, Eastlake, Filer City, and Stronach, until to-day this district produces about one-third of the entire Michigan output of salt.

As in the case of the Saginaw valley and Lake Huron districts, the salt industry here has been associated with the lumber industry. Both the grainer and vacuum pan processes are in operation, exhaust steam from the saw mills being utilized in the evaporation.

The brines from which the salt is manufactured are obtained by dissolving the rock salt of the Salina formation. The salt beds have a thickness varying from 20 to 34 feet and are found at a depth ranging from 1,912 feet at the old Wheeler and Canfield well near the lake (Michigan) and 1,930 feet at Stronach, to 1,988 feet at Eastlake.

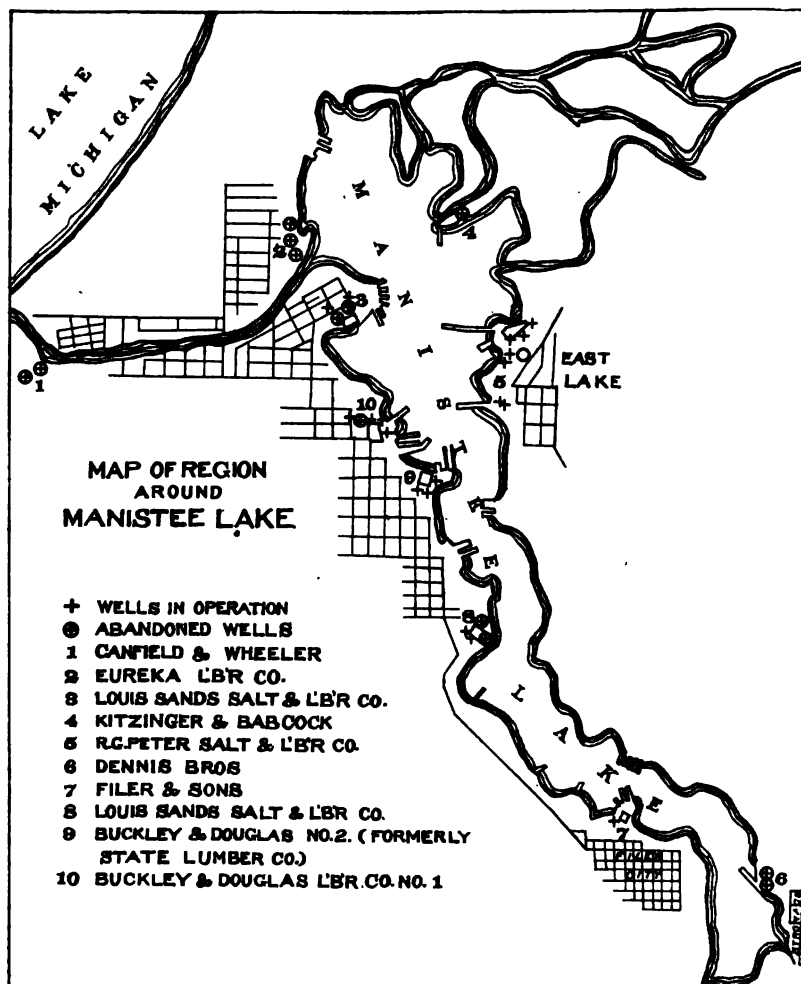


Figure 41. Map of the region about Manistee Lake showing location of producing and abandoned salt wells.

The characteristic geological section of this district is shown by the following well record compiled from the samples taken from the Peters well No. 7, the samples having been kindly furnished by Mr. R. A. Nickerson.

R. G. Peters Salt and Lumber Co., Well No. 7, N. W. $\frac{1}{4}$, N. W. $\frac{1}{4}$, Sec. 7, T. 21 N., R. 16 W., Alt. 600.

	Thickness.	Total depth.
Pleistocene drift.....	593	593
Antrim.....		
Soft blue shale.....	4	597
Bluish gray calcareous shale.....	203	800
Hard black shale.....	187	987
Traverse.....		
Porous limestone showing well developed crystals of dolomite.....	347	1325
Sandy limestone. Pronounced effervescence.....	75	1400
Grayish black limestone containing crystals of selenite. Harder than at 978.....	25	1425
Reddish brown limestone containing some bituminous matter.....	25	1450
Same. Somewhat softer and more bituminous. Samples at 1450 and 1475.....	37	1487
Top of "Cave rock." Soft grayish blue argillaceous limestone.....	13	1500
Calcareous shale. Softer and lighter colored than at 1487.....	50	1550
Crumbly soft shale resembling blue clay. Some effervescence.....	45	1595
Hard black limestone.....	10	1605
Dundee.....		
Hard grayish brown (buff) limestone containing sand.....	15	1620
Reddish brown limestone containing bituminous matter.....	18	1638
Grayish shaly limestone. Sets up hard in bottle.....	7	1645
Fairly hard gray limestone. Does not set up in the bottle as does the above. Samples also at 1650 and 1652 which appear successively harder.....	11	1656
Softer brown limestone containing bituminous matter.....	2	1658
Monroe (Salina not separated).....		
Harder grayish brown limestone.....	3	1661
Same as above except softer.....	19	1680
Hard reddish brown limestone.....	20	1700
Decidedly reddish limestone, softer than above.....	62	1762
Brown limestone with coating of gypsum on the grains.....	18	1780
Very hard yellow limestone.....	20	1800
Somewhat softer with more of a reddish tinge.....	10	1810
Buff limestone.....	10	1820
Softer brown limestone containing some gypsum.....	10	1830
Hard gray limestone. Sample at 1850 appears somewhat harder.....	32	1862
"Cave rock." Cherty limestone.....	8	1870
Soft grayish brown limestone.....	25	1895
Dark gray dolomitic limestone.....	10	1905
Dark gray porous dolomitic limestone containing selenite crystals in the cavities.....	15	1920
Harder brown limestone containing gypsum.....	10	1930
Same. Softer and darker colored.....	10	1940
Similar to above but lighter in color and containing gypsum.....	24	1964
Blackish gray porous limestone with gypsum.....	16	1980
Salt at 1980.....		
Total depth of well.....		2000

Note: Gas was encountered at 730, 1100, 1654, and 1911 to 1916 it increased rapidly. Oil was encountered from 1916 to 1925.

There is sufficient flow of water in the rocks to cause the solution of the rock salt, so that it is not necessary to pump water into the wells for that purpose. In some instances, a small amount of water is pumped into the wells between the casing and the tubing to prevent the corrosive action upon the tubing of gases, especially the hydrogen sulphide which comes from the Devonian shales.

Three grades of salt are manufactured,—medium, granulated, and packers—and the product is shipped largely by boat to Chicago and Milwaukee for western distribution. Plate VB shows a boat loading bulk salt at the No. 1 plant of the Louis Sands Salt and Lumber Co.

The location of all the plants now in operation as well as those which have operated in the past is shown in Fig. 41.

The salt inspected in the Manistee district since the establishment of the industry is given in the following table.

TABLE XXXVI.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1881.....	1,642	1891.....	1,125,696	1901.....	2,670,094
1882.....	41,562	1892.....	1,294,139	1902.....	2,332,507
1883.....	48,544	1893.....	1,303,042	1903.....	2,202,054
1884.....	123,033	1894.....	1,134,244	1904.....	2,283,459
1885.....	432,637	1895.....	1,318,139	1905.....	1,921,634
1886.....	683,103	1896.....	1,416,709	1906.....	2,005,881
1887.....	871,575	1897.....	1,827,427	1907.....	1,966,335
1888.....	850,383	1898.....	1,555,006	1908.....	2,329,940
1889.....		1899.....	2,205,182	1909.....	2,107,489
1890.....	1,006,525	1900.....	2,253,769	1910.....	2,081,048

Companies.

R. G. Peters Salt and Lumber Co. (Plate VI A and B), Eastlake, Mich. Incorporated, March 2, 1884. Capital stock, \$1,000,000.00. President, R. G. Peters; vice president, Wm. H. Anderson; secretary, A. W. Farr; assistant secretary-treasurer, J. R. Peters; assistant to the president, R. A. Nickerson.

This plant, which is the largest in the state, employs both the vacuum pan and grainer processes. The vacuum pans, of which there are three, are run "triple effect" and operate on exhaust steam. They are thirty feet in diameter and have a daily capacity of 4,500 barrels. On the average they are run at only sixty per cent capacity. There are twenty-one grainers (120'x16'x22") which are constructed of wood and equipped with reciprocating rakers, with a capacity of 3,200 barrels and an average daily output of 1,600 barrels. Exhaust steam is also employed in the grainers. Seven wells are in operation and one has been abandoned. The average depth of the wells is about 2,000 feet and the salt bed ranges from twenty to thirty feet in thickness. The brine from the wells is stored in three cisterns (300'x24'x8') and settled in the same number of preheaters which are of the same size as the cisterns. The pumping is done with compressed air from a depth of 850 feet under a pressure of 250 pounds. The storage capacity of the plant is 325,000 barrels. Two grades of salt are manufactured, granulated in the vacuum pans and medium in the grainers. The product, which is sold to the Morton Salt Co., is shipped almost entirely by boat, in bulk and barrels. 220 men are employed.

Louis Sands Salt and Lumber Co. (Plate VII A and B), Manistee, Mich. Incorporated, March 16, 1905. Capital stock, \$1,000,000.00. President and general manager, R. W. Smith; 1st vice president, Isabella Sands; 2nd vice president, Louis M. Sands; secretary, Geo. M. Clifton; treasurer, Geo. M. Burr.

Two plants are operated by this company. The No. 1 plant which is located in the third ward may be described as follows: The brine which is obtained from two wells, respectively 2,012 and 2,014 feet deep, the pumping being done with compressed air under 250 to 300 pounds

pressure, is evaporated in cement grainers of which there are fifteen (150'x12'x22'), the salt being removed by automatic rakers. There is one cistern (160'x24'x9') from which the brine passes into five preheaters of which four are 155'x12'x7' and one, 124'x24'x7'. The temperature of the preheaters is about 145° to 160° F. The daily capacity is 1,000 barrels and the storage capacity, 67,000 barrels. Two grades of salt, medium and packers, are produced.

Plant No. 2 is located in the fourth ward and is equipped with eleven grainers, ten of which are 150'x12'x20" and one is 160'x9'x20". During the day, exhaust steam is obtained from the saw mill and at night live steam is used. In addition to the refuse from the saw mill, about thirty tons of coal per week are used for fuel. The temperature of the grainers is 185° to 190° F. and the tail-water which leaves the grainer at a temperature of 150° F. is used in the four preheaters (2—190'x13'x7.5'; 1—190'x15'x7.5'; 1—150'x10.5'x8.5'). The brine is obtained from two wells, respectively 1,962 and 1,969 feet deep. The salt bed has a thickness of thirty to thirty-two feet. The pumping is done with compressed air from a depth of 700 feet. The daily capacity of the plant is 600 barrels and the storage capacity, 60,000 barrels in bulk and 8,000 barrels in barrels. The product of both plants is sold to the Morton Salt Co., and is transported by boat. From the No. 1 plant the salt is shipped both in barrels and bulk in about equal amounts, while from the No. 2 plant the entire output is shipped in barrels. One hundred and twelve men are employed.

Buckley and Douglas Lumber Co. (Plate VIIIA), Manistee, Mich. Incorporated, December 31, 1892. Capital stock, \$1,000,000.00. President, Edward Buckley; vice president, ...; secretary, T. J. Elton; treasurer, Edward Buckley.

As at the Peters plant, both the vacuum pan and grainer processes are here in operation. The vacuum pans, of which there are two, are the "single effect" type and have a diameter of eleven feet. There are fifteen cement grainers (150'x12'x22'), twelve of which are equipped with automatic rakers and make medium salt, and three which utilize the tail-water and make packers salt. Both live and exhaust steam are employed and a considerable amount of coal is used for fuel. The company has four wells in operation and one which has been abandoned. Fig. 42 shows the condensed record of well No. 5 together with the casings and equipment for pumping the brine with compressed air. The brine is stored in two cisterns (230'x12'x8' and 170'x12'x8') and is settled in six preheaters (3—200'x12'x8' and 3—150'x12'x8'). The preheaters are carried at a temperature of about 160° F. The capacity of the plant is about 670,000 barrels per annum, the grainers being run the entire year and the vacuum pans for eleven months. The storage

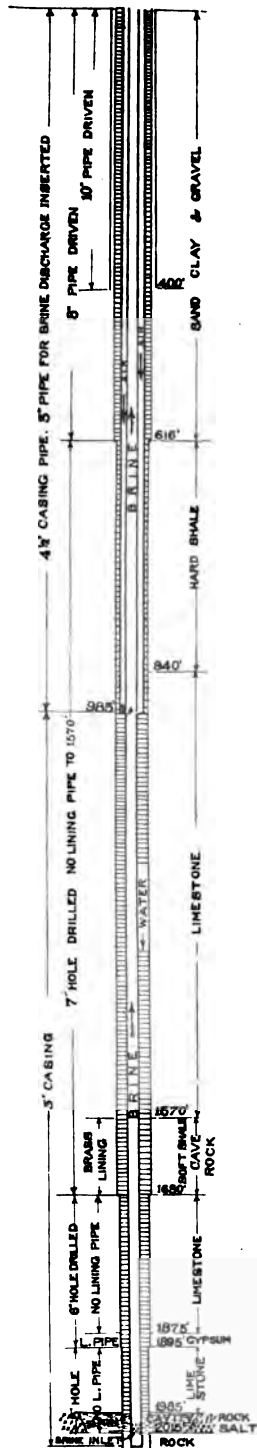


Figure 42. Section of the Number 5 well of the Buckley and Douglas Lumber Company, Manistec, Michigan, showing the geology and method of piping (after Hubbell).

capacity is 450,000 barrels. The product, which consists of granulated, medium and packers salt, is sold direct and shipped entirely by rail.

State Lumber Co.²² (Plate VIIIB), Manistee, Mich. Re-incorporated, April 18, 1907. Capital stock, \$50,000.00. President, Patrick Noud; vice president, Thomas J. Noud; secretary-treasurer and general manager, Robert Blacker.

At the plant of this company only the grainer system is employed. There are seventeen grainers (170'x10.5'—12'x14'), all of which are constructed of wood. Eight of the grainers are equipped with automatic rakers and nine are lifted by hand. Both live and exhaust steam are used and the temperature of the grainers varies from 170° to 190° F. The brine is supplied by three wells having depths of 1,993, 1,995 and 2,003 feet respectively. The thickness of the salt bed in all of the wells is about twenty-five feet. The pumping is done with compressed air at a pressure of 275 to 300 pounds to the square inch and the air line extends to a depth of 900 feet. The brine is settled in three preheaters (212'x15'x8') which are carried at a temperature of 160° to 170° F. The plant runs about ten and one-half months in the year and has an annual capacity of 290,000 barrels, with a storage in bulk of 75,000 barrels.

Filer and Sons (Plate IXA), Filer City, Mich. E. G. Filer, managing partner. The plant contains one vacuum pan thirteen feet in diameter which uses the exhaust steam from the saw mill, refuse being employed as fuel. The brine is obtained from one well which was put down originally in prospecting for oil. The rock salt is encountered at 1,955 feet and has a thickness of 31 feet. The pumping is done with a beam plunger pump, the pumping station being 529 feet below the top of the well. Five settling tanks, all of which are piped for steam, are used alternately as cisterns and preheaters. The temperature of the preheaters is maintained at about 170° to 180° F. According to Mr. Filer, a temperature of 172° F. gives the best results for the removal of gypsum in the preheaters. The capacity of the plant is 500 barrels of granulated salt per day and the plant operates about six months during the year. The storage capacity is 80,000 barrels.

ST. CLAIR COUNTY.

In 1882,²³ a well was sunk by the Marine City Stave Co., at Marine City, which, at a depth of 1,633 feet, encountered a bed of rock salt which was penetrated 115 feet without passing out of the salt. The following year a salt block was erected and a small amount of salt was

²²This company suspended operations in the fall of 1910 and the plant is now operated by the Buckley and Douglas Lumber Co., as their No. 2 plant.

²³Report of the State Salt Inspector for 1882, p. 8.

produced. Later other plants were erected here and also at St. Clair, Port Huron, Algonac and Pearl Beach. At the present time no salt is produced at the two latter places. Perhaps the most striking characteristic of the industry in the St. Clair district is its independence from any other industry. All of the steam blocks in operation use live steam, and coal is employed as fuel. The location of the blocks on the St. Clair river provides cheap transportation for both the fuel and the finished product. The sites of most of the plants are shown in Figs. 43 and 44.

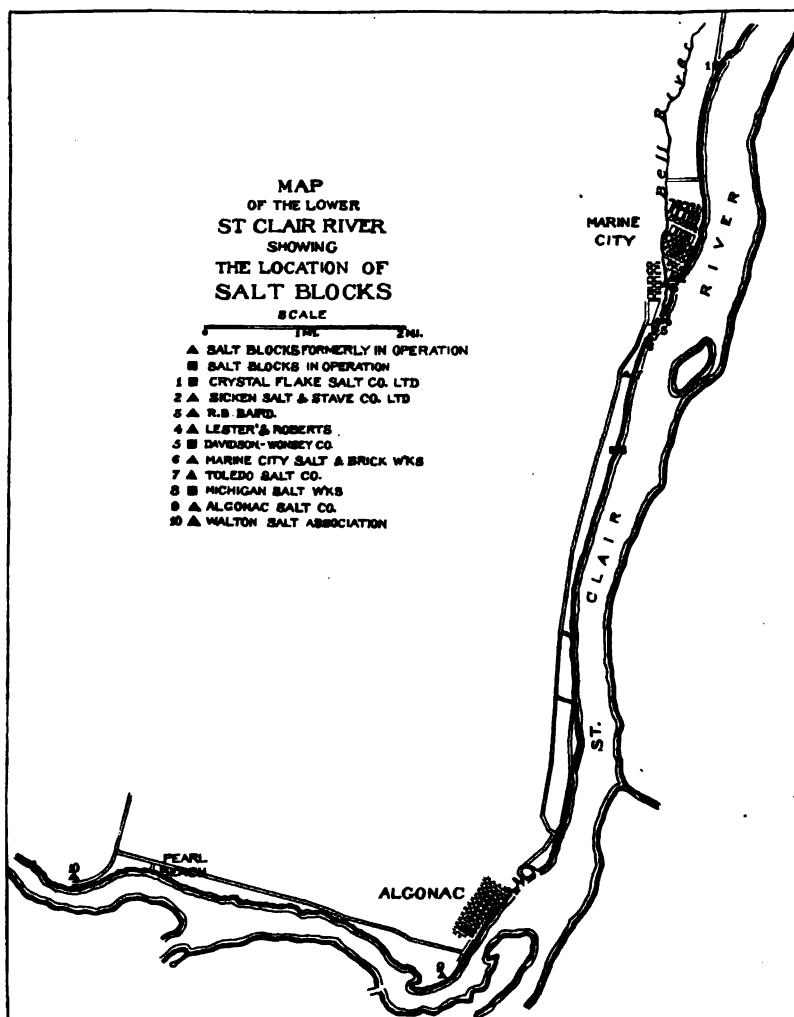


Figure 43. Map showing location of salt blocks along the St. Clair river.

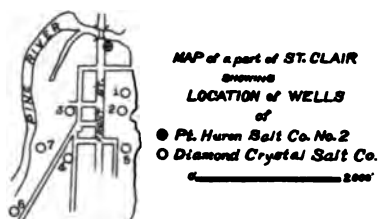


Figure 44. Showing the location of wells of the Diamond Crystal Salt Company and the Port Huron Salt company No. 2, St. Clair, Michigan.

Four different processes, vacuum pan, Alberger, grainer and open pan are in operation. All of these processes may be seen at St. Clair, the first three at the plant of the Diamond Crystal Salt Co., and the fourth at the No. 2 plant of the Port Huron Salt Co., on the adjoining property.

The brines are formed by the solution of the rock salt of the Salina formation. The salt beds vary somewhat in thickness and position at the different manufacturing points within the district as may be seen from the following well records.

Port Huron Salt Co., No. 5. well. Sec. 32, T. 6 N., R. 17 E. A. T. 590.'

Record from driller's log and samples compiled by A. C. Lane.

	Driller's log.	Samples.
0-100	Unconsolidated deposits.	
100-305	Chocolate soft rock.	Brown bituminous shale with pyrite.
305-310		Blue argillaceous limestone.
310-327	Gray limestone.	Briak effervescence.
327-337	Soapstone.	Soft blue shale. Calcareous.
337-393	Gray lime.	Blue and white mixed.
393-415	Soapstone.	Thin bedded blue limestone.
415-425	Gray lime.	
425-601	Soapstone.	
601-710	Light lime.	Limestone. Fierce effervescence.
710-715	Lighter lime.	Limestone, pure.
715-730	Gray lime.	
730-793	Lime.	Limestone, pure. Fragments coarse.
793-835	Mixed lime.	Lime and gypsum.
835-849	Lime and gypsum.	Mainly gypsum. Some selenite.
849-980	Limestone.	Dark dolomite, oily smell.
980-985	Black lime. Show of oil.	Oily dolomite or oil sand.
985-1240	Gray lime.	Dolomite very light.
1240-1300	Hard gray lime.	Dolomite.
1300-1305	Slate.	Dark blue dolomite.
1305-1325	Soft clay.	Soft blue shale. Slow effervescence.
1325-1332	Slate rock.	Blue shale, harder.
1332-1500	Slate.	Dolomite and anhydrite.
	(1500, 1500, 1510, and 1498 in the, other wells).	
1500-1595	Salt and shale mixed.	
1595-1685	Red lime.	Dolomite.
1685-1690	Salt.	
1690-1710	Red lime.	
1710-1740	Salt.	
1740-1750	Soft lime.	
1750-1775	Salt.	
1775-1887	Hard lime.	
1887-1920	Salt.	
1920-1965	Soft shale.	
1965-1991	Hard lime.	Dolomite.
1991-2190	Salt.	
2190-2195	Hard lime.	

Diamond Crystal Salt Co., St. Clair. Composite record²⁴ of wells Nos. 6 and 7 from driller's log. Started, February 10, 1909. Record furnished by Mr. F. W. Moore.

0-115	Clay.
115-153	Hard pan and gravel.
153-305	Blue shale or slate.
305-500	Brown shale.
500-512	Lime.
512-522	Blue shale.
522-542	Lime.
542-565	Blue shale.
565-590	Lime.
590-700	Soapstone.
700-710	Lime.
710-760	Soapstone.
760-820	Lime.
820-830	Sharp hard lime.
830-1120	Lime.
1120-1128	Hard brown lime.
1128-1160	Lime.
1160-1180	Hard sandy lime.
1180-1200	Very hard lime.
1200-1345	Very sharp lime.
1345-1400	Lime.
1400-1485	Very hard lime.
1485-1490	Mud vein.
1490-1495	Red shale.
1495-1570	Lime.
1570-1600	Hard brown lime.
1600-1620	Hard gray lime.

(First salt at 1630 in No. 5, 1620 in No. 6, and 1623 in No. 7.)

1623-1653	Salt.
1653-1675	Lime.
1675-1685	Hard brown lime.
1685-1705	Lime.
1705-1743	Very hard lime.
1743-1763	Salt.
1763-1768	Lime.
1768-1778	Salt.
1778-1854	Shale.
1854-1884	Salt.
1884-1892	Lime.
1892-1902	Salt.
1902-1912	Lime.
1912-2020	Salt.
2020-2025	Lime.
2025-2130	Salt.
2130-2135	Lime.
2135-2165	Salt.
2165-2200	Brown lime.

Michigan Salt Works, Marine City, Well No. 2. Drilled in 1898. Log furnished by Mr. S. R. McLouth.

0-150	Clay.
150-165	Hardpan.
165-200	Clay and gravel.
200-400	Black slate.
400-415	Lime.
415-465	Soapstone. Hard to mill. Could cut about four feet per hour with 4" stem 43' long.
465-575	Darker and harder.
575-730	Lime. Averaged two feet per hour with 5 1/2" stem, 38' long. Struck sulphur water at 710 and salt water at 725.
730-780	Brownish limestone. Soft. Easy on bits.
780-795	
795-800	Streak of gypsum.
800-825	Hard streak of lime.
825-830	Gypsum.
830-850	Hard.
850-860	Gypsum.
860-870	
870-875	Hard streak of lime.
875-900	Soft blue gypsum. (Anhydrite?).
900-970	Limestone.

Shelly at 900.

²⁴The record of the No. 7 well was not saved until after the first salt bed was reached at 1623 feet, compared with 1620 in No. 6. From the top of the first salt the record of the No. 7 well is used since it passed through the last salt bed whereas the No. 6 well did not.

970-1000.....	Averaged 15" per hour.
1000-1040.....	Flint limestone. Good drilling. 18' in twelve hours.....
1040-1100.....	Same.
1100-1160.....	Sandy limestone. Hard.
1160-1300.....	Hard.
1300-1370.....	Caving rock and gypsum.
1370-1400.....	Record lost.
1400-1500.....	Hard.
1500-1570.....	Same.
1570-1595.....	Salt. (The record at this point is not clear, reading 10' lime, 10' salt, to 1605. Lime to 1612 - lime 11'. Top of salt 1623).
1623-1751.....	Salt.
	Lime at 1751.

The production of salt in St. Clair county by years is given in Table XXXVII.

TABLE XXXVII.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1883.....	4,780	1893.....	285,583	1903.....	913,954
1884.....	74,671	1894.....	404,628	1904.....	1,309,764
1885.....	125,014	1895.....	463,094	1905.....	1,540,513
1886.....	250,602	1896.....	310,917	1906.....	1,365,256
1887.....	328,699	1897.....	297,064	1907.....	1,632,969
1888.....	325,616	1898.....	596,547	1908.....	1,543,844
1889.....		1899.....	432,929	1909.....	1,561,352
1890.....	242,011	1900.....	509,776	1910.....	1,296,605
1891.....	255,525	1901.....	871,915		
1892.....	347,242	1902.....	824,984		

Companies.

Port Huron Salt Co. (Plate IXB). Offices 717 Ry. Exchange Bldg., Chicago, Ill.; plants, Port Huron and St. Clair, Mich. Incorporated, January, 1900. President, Joy Morton; vice president, Mark Morton; secretary, Sterling Morton; treasurer, Daniel Peterkin; general manager, Otto Huette.

Two plants are operated by this company. The No. 1 plant is located about one mile south of the Port Huron city limits, and contains both a grainer and a vacuum pan block, in addition to which the plant has apparatus for the manufacture of table salt. The grainer block contains nine grainers, five, 18' wide and four, 14' wide. The vacuum pan is twelve feet in diameter. Live steam, supplied by fourteen Wicks boilers, is employed in evaporating the brine, which is obtained by dissolving the rock salt of the Salina formation through the medium of eight wells. The wells have a depth of about 2,200 feet, although the first salt bed is encountered between 1,500 and 1,600 feet. The annual production is about 400,000 barrels of which approximately one-half is table salt. The daily capacity is 3,000 barrels and the number of men employed is 200.

The No. 2 plant is located at St. Clair and was formerly operated by Thomson Bros. It is an open pan block containing five English direct heat pans (3-18'x77' and 2-18'x87'). The brine is furnished by one well, about 1,700 feet in depth. Coal is used for fuel and about forty men are employed in operating the plant.

Diamond Crystal Salt Co. (Plate X A and B), St. Clair, Mich. Capital stock, \$650,000.00. President, C. F. Moore; vice president, P. R. Moore; secretary-treasurer, F. Moore; general manager, H. Whiting.

Three different processes, the vacuum pan, grainer, and the Alberger, are employed by this company. The chief process is the Alberger and the block contains five pans (44'x88'x12"). The grainer block contains six steel grainers and the vacuum pan block, one six-foot vacuum pan. Live steam, supplied by sixteen Wicks boilers, is used in evaporating the brine which is furnished by seven wells, ranging in depth from 1,630 to 2,200 feet. The daily capacity is 2,850 barrels. At present the plant is operating at about fifty per cent capacity and eighty per cent of the output is turned into table and dairy salt. 200 men are employed.

Crystal Flake Salt Co., Ltd. (Plate XIA). Plant, Marine City, Mich. Offices, Minneapolis, Minn. President, J. E. Vebleu.

The plant operated by this company contains six cement grainers (128'x12'x22"). Live steam is employed in evaporating the brine, which is furnished by one well 1,675 feet in depth. The average daily output is 320 barrels of medium and 18 barrels of packers salt. The storage capacity is 11,500 barrels and the number of employees, eight.

Davidson-Wonsey Co. (Plate IIA), Marine City, Mich. Capital stock, \$60,000.00. President, James Davidson; vice president, C. L. Doyle; secretary-treasurer, Palmer Davidson.

The company operates a vacuum pan block containing two "single effect" pans, twelve feet in diameter. Live steam for the evaporation of the brine is furnished by five marine boilers. The brine is supplied by two wells, respectively 1,750 and 1,900 feet in depth. The daily capacity is 1,000 barrels and the storage capacity is 21,500 barrels. Forty men are employed.

Michigan Salt Works (Plate XIB), Marine City, Mich. Re-incorporated, 1903. Capital stock, \$100,000.00. President, Wm. A. Hazard; vice president, Edwin J. O'Bryan; secretary-treasurer, Sidney C. McLouth.

The salt block is located about two miles south of Marine City and contains eight grainers, as follows: two cement grainers (164'x18'x22"), two steel V-grainers (100'x18'x6'), one wood and three cement grainers (120'x12'x22"). Steam for evaporating the brine is furnished by five marine boilers. The brine is supplied by two wells, respectively 1,630 and 1,851 feet in depth. The daily capacity is 800 barrels, about 20% of the output being turned into table salt. The storage capacity is 60,000 barrels and the number of employees, seventy-five.

MASON COUNTY.

The salt industry in Mason county has been centered around the city of Ludington. The only plant outside of the city was that of the Butters Salt and Lumber Co., located at Buttersville, across Pere Marquette lake from Ludington. This plant which burned in the fall of 1909 (Plate XIIIA) and has not been rebuilt, is of historical interest as the home of the first vacuum pan used in the manufacture of salt in Michigan.

The search for salt was begun at Ludington in 1883 when, on June second, drilling was started by the Pere Marquette Lumber Co. The well was completed in 1885 at a depth of 2,220 feet.²⁵ The following year Mason county entered the list of producers with an inspection of 79,221 barrels. The industry advanced rapidly as is shown by the following table which gives the inspection to the close of 1910.

TABLE XXXVIII.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1886.....	79,221	1895.....	531,542	1904.....	512,505
1887.....	208,489	1896.....	547,843	1905.....	665,001
1888.....	280,715	1897.....	522,324	1906.....	679,187
1889.....		1898.....	557,838	1907.....	974,861
1890.....	387,617	1899.....	560,123	1908.....	679,564
1891.....	444,231	1900.....	718,654	1909.....	851,669
1892.....	341,668	1901.....	650,689	1910.....	818,728
1893.....	474,681	1902.....	514,745		
1894.....	500,546	1903.....	466,125		

The brine is obtained, as in Manistee county, by the solution of the rock salt of the Salina formation, which is encountered at a depth of about 2,275 feet. The geological section is shown by the following well records.

Anchor Salt Co. well No. 4.

Completed, March, 1908. J. H. Brogan, driller. Record furnished by Mr. P. Hardy.

²⁵The record of this well is given in Geol. Sur. Mich., Vol. V, Part II. Plate XXVII.

	Thickness.	Total depth.
Sand and gravel.....	267	267
Clay.....	27	294
Hardpan.....	19	313
Clay.....	36	349
Sand.....	85	438
Clay.....	5	443
Hardpan and sand.....	25	468
Sand.....	40	508
Hardpan and gravel.....	2	510
Sand.....	4	514
Gravel.....	4	518
Sand.....	34	552
Gravel.....	6.5	658.5
Brown shale.....	3.5	562
Sand.....	1	563
Shale.....	10	573
Sand and gravel.....	2	575
Shale.....	60	635
Lime stone.....	14	649
Slate (probably hard shale).....	24	673
Limestone.....	6	679
Red limestone.....	17	696
Lime.....	74	770
Sharp lime.....	112	882
Lime.....	18	900
Shale.....	167	1067
Lime.....	20	1087
Shale.....	146	1233
Black shale.....	29	1262
Brown shale.....	176	1438
Black shale.....	58	1496
Lime.....	44	1540
Water at 1536.....		
"Trenton" lime.....	37	1577
Water at 1569.....		
Brown sandstone.....	108	1685
Gypsum at 1586 and a vein of sand at 1617.....		
Sharp sandstone.....	10	1695
Black sandstone.....	46	1741
Sharp sand.....	29	1770
Black sand.....	8	1778
Brown sand.....	57	1835
Dark sand.....	13	1848
Sharp sand.....	8	1856
Black sand.....	9	1865
Brown sand.....	20	1885
Yellow sand.....	33	1918
Brown sand.....	34	1952
Black sand.....	27	1979
Sharp sand.....	7	1986
Streak of shale.....	3	1989
Limestone.....	6	1995
Shale.....	69	2064
Black lime.....	10	2074
Brown lime.....	235	2309
Salt.....	20.5	2329.5
Bottom of salt at 2329.5.....		

Anchor Salt Co. Well No. 5. Driller's log furnished by Mr. J. H. Brogan, driller. The top of No. 5 is 47 feet below the top of No. 4.

	Thickness.	Total depth.
Sand.....	90	90
Gravel.....	42	132
Sand.....	92	224
Gravel and hardpan.....	176	400
Sand.....	90	490
Blue clay.....	44	534
Slate.....	61	595
Blue lime.....	15	610
Slate and limestone.....	725	1336
Brown shale.....	147	1482
Hard limestone.....	468	1960
"Cave".....	80	2030
Hard limestone.....	233	2263
1st salt.....	20	2283
Hard white lime.....	14	2297
2nd salt.....	12	2309
Limestone.....	25	2334
3rd salt.....	7	2341
Limestone.....	13' 9"	2354' 9"
4th salt.....	5	2359' 9"
Limestone.....	44' 9"	2404' 6"

The No. 3 well with a total depth of 2,360 feet showed three beds of salt, respectively 20, 9, and 8 feet in thickness. This well which has about the same elevation as No. 5 is located about 1,000 feet west and 700 feet north of it.

At present three plants are being operated by two companies. Their capacity is given by the state salt inspector as 1,650,000 barrels.

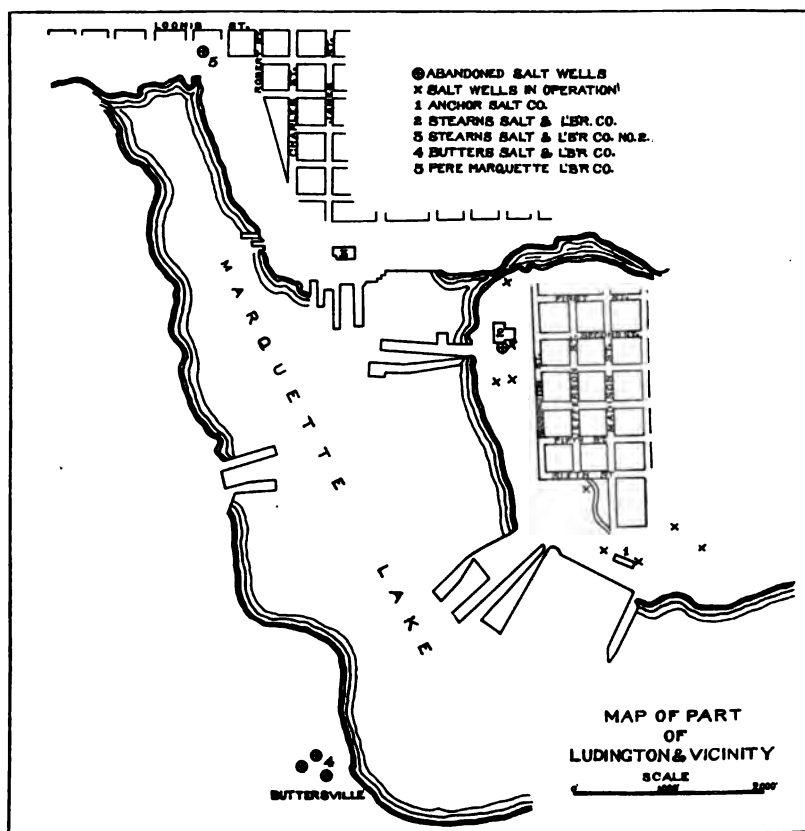


Figure 45. Map of a portion of Marquette lake showing the location of salt wells in that region.

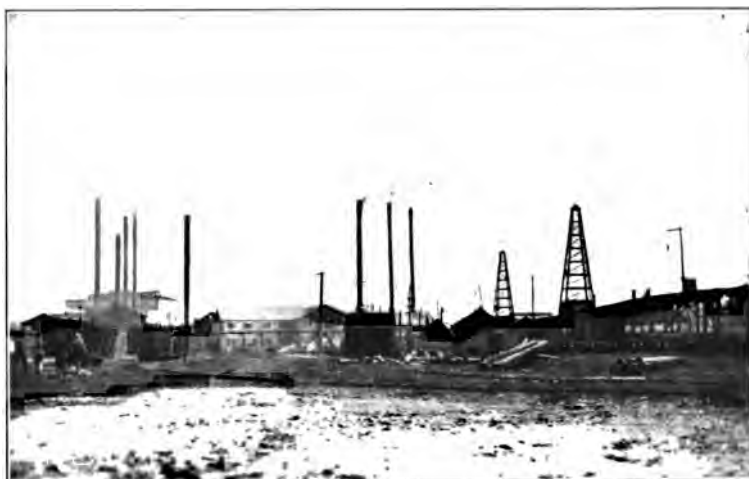
Companies. (See Fig. 45.)

Stearns Salt and Lumber Co. (Plate XIIB), Ludington, Mich. Incorporated. Capital stock, \$500,000.00. President, J. S. Stearns; vice president, W. T. Culver; secretary-treasurer, R. L. Stearns.

Two plants are operated by this company. The Number 1 plant is equipped with nineteen wooden grainers (150'x12'x22'), thirteen of which are fitted with mechanical rakers. The grainers are carried at a temperature of 170° F., when making medium salt, and have an average daily capacity of 1,000 barrels. When making packers salt the daily capacity is reduced to 300 barrels. The evaporation is carried on entirely with exhaust steam, which is obtained from the saw mill, planing mill, and Stearns Light and Power Co. Both refuse from the saw mill and coal are used for fuel. The company has three wells in operation, one abandoned, and one under construction. The brine



A. R. G. PETERS SALT AND LUMBER CO., EASTLAKE, MICHIGAN.



B. R. G. PETERS SALT AND LUMBER CO., EASTLAKE, MICHIGAN.



A. LOUIS SANDS SALT AND LUMBER CO., NO. 1, MANISTEE, MICHIGAN.



B. LOUIS SANDS SALT AND LUMBER CO., NO. 2, MANISTEE, MICHIGAN.



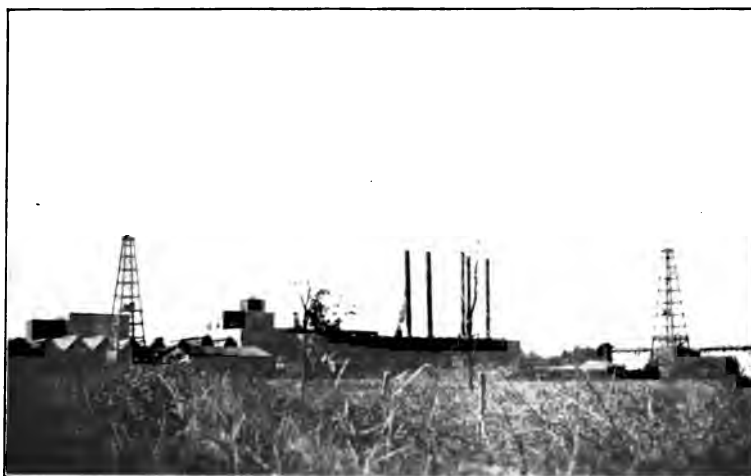
A. BUCKLEY AND DOUGLAS LUMBER CO., NO. 1, MANISTEE, MICHIGAN.



B. BUCKLEY AND DOUGLAS LUMBER CO., NO. 2, (STATE LUMBER
CO.), MANISTEE, MICHIGAN.



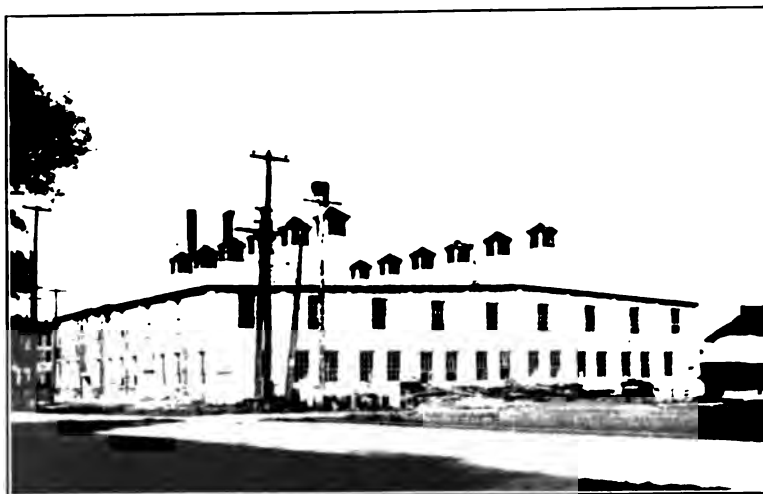
A. FILER AND SONS, FILER CITY, MICHIGAN.



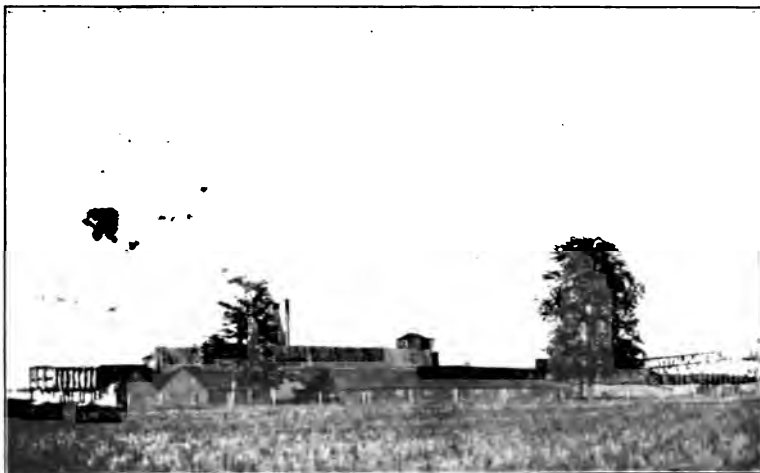
B. PORT HURON SALT CO., PORT HURON, MICHIGAN.



A. DIAMOND CRYSTAL SALT CO., ST. CLAIR, MICHIGAN.



B. DIAMOND CRYSTAL SALT CO., ST. CLAIR, MICHIGAN. GRAINER
BLOCK.



A. CRYSTAL FLAKE SALT CO., LTD., MARINE CITY, MICHIGAN.



B. MICHIGAN SALT WORKS, MARINE CITY, MICHIGAN.



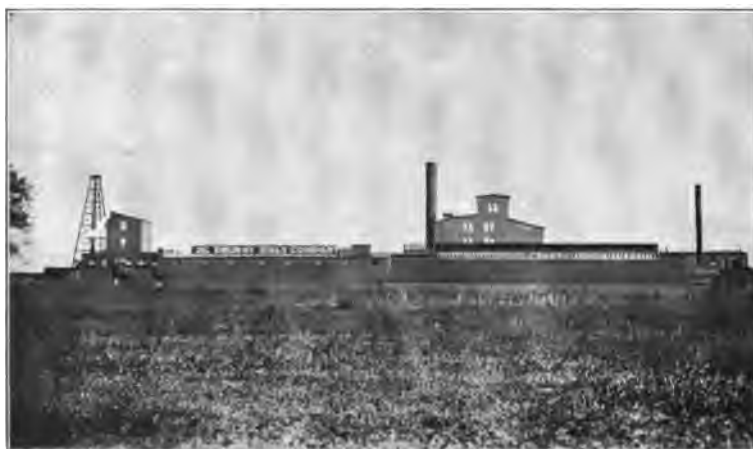
A. RUINS OF THE BUTTERS SALT AND LUMBER CO., BUTTERSVILLE,
MICHIGAN.



B. STEARNS SALT AND LUMBER CO., LUDINGTON, MICHIGAN.



A. ANCHOR SALT CO., LUDINGTON, MICHIGAN.



B. DELRAY SALT CO., DELRAY, MICHIGAN.

is pumped with compressed air and stored in five rectangular cisterns (4—100'x13'x8.5' and 1—65'x18'x6'). Before entering the grainers, the brine is settled at a temperature of 130°—135° F. in preheaters of which there are six (4—150'x12'x8.5' and 2—65'x18'x6'). The storage capacity is 160,000 barrels in bulk and about 7,000 barrels in barrels. The product is sold direct, about four-fifths in barrels. Shipments are made both by rail and boat, the market being south and west of Michigan. At the time of visitation, in addition to the above, a twelve foot "single effect" vacuum pan was being installed, and the company was planning the addition of dryers and screens to make table salt.

The Rapid Evaporator Co., Detroit, Mich., likewise have under construction a "quadruple effect" vacuum pan of the Fallar type, the pans of which are rectangular, 12 by 9 feet, with an expected capacity of 30 tons of coarse or 90 tons of fine salt on a consumption of 24,000 pounds of steam. The Stearns company were to furnish the brine and steam for this plant.

The Stearns plant No. 2 is owned by the Cartier Lumber Co., and leased to the Stearns Co. Six wooden grainers (150'x12'x22") are in operation, the brine being supplied from the No. 1 plant and the steam being obtained from the saw mill of the Cartier Lumber Co. The temperature of the grainers varies from 175° to 190° F. The salt is lifted by hand every twenty-four hours. The brine is settled in one preheater (110'x16'x7') at a temperature of 170° to 180° F. The daily capacity is 400 barrels and the storage capacity is 15,000 barrels in bulk and 4,000 barrels in barrels. The number of men employed is twenty, and the plant is operated about eight to nine months a year.

Anchor Salt Co. (Plate XIII A). Plant, Ludington, Mich.; offices, Railway Exchange Bldg., Chicago, Ill. President, Joy Morton; vice president, Mark Morton; secretary, Sterling Morton; treasurer, Daniel Peterkin.

This company took over the Percy block and has replaced it with a vacuum pan block. The vacuum pan house is constructed of brick and contains three pans of the Ray type, respectively 18, 19 and 20 feet in diameter, which are run "triple effect," with provision for a fourth pan. The evaporation is carried on with live steam, coal being used for fuel. This is the only salt block in the Lake Michigan area which is operated independently of the lumber industry. The plant also contains three wooden grainers (150'x12'x22"). These however are not used. The brine, supplied by five wells, the logs of some of which have already been given, is pumped by air pressure and stored in three cement cisterns (44'x16'—12'x136'). The cisterns are constructed in the side of the bluff shown at the right in Plate XIII A so that after being allowed to settle the brine may be drawn by

gravity into the pans or hot settlers of which there are three (160'x14'x10'). The rated daily capacity of the plant is 2,000 barrels and the storage capacity, 150,000 barrels in bulk and 6,000 barrels in barrels. Most of the product is shipped in bulk by boat to Chicago.

WAYNE COUNTY.

The first production of salt in Wayne county was made at the plant of the Detroit Salt Co. at Oakwood in 1895, the total output for that year being 13,077 barrels. The next year blocks were constructed at Ecorse by the Tecumseh Salt Co., and at River Rouge by the Carter Salt Co., the former being a vacuum pan and the latter an open pan block. Neither of these plants produced any salt until 1897, when a production was also reported by the Morton Salt Co., at Wyandotte and by Brownlee and Co., at River Rouge. Since then the industry has grown quite rapidly and since 1906 the annual production has averaged over 1,000,000 barrels.

In 1906 a radical departure in the salt industry of Michigan was made, when the Detroit Salt and Manufacturing Co., started sinking a shaft at Oakwood. Innumerable difficulties were encountered, the greatest perhaps being the strong flows of water which were struck at various depths, the strongest occurring in the upper portion of the Sylvania sandstone at a depth of 420-430 feet. Some loss of life was caused by hydrogen sulphide fumes, also financial difficulties beset the company and it was reorganized as the Detroit Salt Co., which succeeded in reaching the rock salt and starting production in 1910. Operations being unsuccessful, the company defaulted the interest on its bonds and went into the hands of a receiver in the spring of 1911. The plant was later taken over by the Watkins Salt Co. of Watkins, N. Y.²⁶ and in 1913 by the International Salt Co.,²⁷ through the purchase of the stock of the Watkins company. The shaft is now²⁸ reported to be 1,150 feet deep and the production 12,000 tons per month.

The salt deposits of the Salina formation in Wayne county are probably of more importance however, as a source of part of the raw materials for the manufacture of soda ash, bleach, caustic, etc., than as a source of salt itself. Large plants are operated by the Solvay Process Co. at Solvay, the Michigan Alkali Co. at Ford City and Wyandotte, and the Pennsylvania Salt Manufacturing Co. at Wyandotte, the last named company being the only one of the three to produce any salt and it is here merely a by-product. The processes employed by these companies are secret and description of the chemical works will not be attempted.

²⁶Detroit News, August 2, 1912.

²⁷Detroit News, January 9, 1913.

²⁸Ibid.

In addition to the rock salt produced at the shaft at Oakwood, three processes are employed in recovering the salt from the brine, the vacuum pan, open pan and grainer. Table salt is also manufactured by a number of the companies. In the main the salt blocks are run independently of any other industry, the exception being that of the Pennsylvania Salt Manufacturing Co.

The brine (the composition of which is shown in analyses) is obtained by solution of the rock salt of the Salina formation. There are a number of salt beds in this district, the beds varying in number, thickness and position from place to place. The general relationships can best be seen from the record of the No. 4 well of the Morton Salt Co., as compiled by Lane²⁹ with references to other wells. This is an exceedingly valuable record as samples were saved every five feet.

Morton Salt Co. Well, Wyandotte.³⁰

Record begins with bed rock and the depths of samples are numbered therefrom. To find the depth from the surface add 62 feet to the sample number.

Pleistocene.		
Muck. Thin clay. Surface deposits.....	62	62
Silurian.		
Monroe above Salina.		
Light buff dolomites at 10 feet, perhaps Colitic.....	75	137
At 20-30 feet rather brisk effervescence, generally moderate to slow, some rounded sand grains.		
Samples 35, 40, 45, 50, 55, 60, 65, 70, 75 feet, light buff with moderate effervescence with acid. Occasional sand grains in 35, 40, 45. Sulphur in 60, and 65.		
Dolomites.....	60	197
Dark brown, bituminous, with sulphur and sometimes pyrites, with moderate effervescence.		
S. 80, 85, 90, 95, 100, 105, and 110 not quite so dark; 115 brown; 120, lighter.		
Compare Church No. 5 down to 290.		
Salina.		
Quartz sand, clear, very fine, most of the grains from .5 to .2 mm., rounded down to somewhere between .1 and .25 mm.	65	262
S. 135, 140, 145, 150, 155, 160 very fine, 165, 170, from 175 on fine, 180, 185, 190, 195. Compare Ford 23, 235-325; Mt. Clemens, 965.		
Dolomite.....	20	282
Light, effervescence moderate, in specks (due to crystals perhaps) faster.		
S. 200, 205, 210, 215. Compare Ford 23, 325-340.		
Silicious dolomite.....	35	317
Dark brown, with red, rust quartz sand and pyrites in spots, and very cherty at the base.		
S. 220 and 225 (with red rusty quartz sand). From 225 to 245 are dark brown, with brisk to moderate effervescence. S. 240 and 245 have rusted pyrite and grains of quartz sand. S. 250 has a lot of chert and quartz. Compare Ford No. 23, 375-435.		
White sand like that above.....	35	352
S. 255, 260, 265, 270, 275, 280, 285.		
Sandy dolomite.....	10	362
Grains rounded down to .16 mm.		
S. 290, 295, dark, with .16 mm. rounded quartz grains which may have dropped in from above.		
Monroe below Salina?.....		362
Cherty dolomite.....	50	412
S. 300, much chert like Edison, Ft. Wayne, well at 625; 305, 310, 315 (drab color). At 320, 325, 330, 335 largely chert; at 340 to 345 almost solid chert, not effervescent.		
Compare Ford No. 23 at 440, and Church No. 5 at 420-520.		

²⁹Lane, A. C., Geol. Sur. Mich., Ann. Rpt., 1908, pp. 97-99.

³⁰In the above reference the location of the well is given as Ecorse. It should be Wyandotte.

Dolomite.	20	432
Dove colored, with relatively little chert.		
S. 350, 355, 360, 365. Compare Ford No. 23, 445, 450, 455, 460, 465.		
Dolomite.	30	462
Bluish, buff, massive.		
Coarse chips at 375-385; S. 370, 375, 380, 385, 390, 395. Compare Edison 462-477.		
Brown dolomite.	15	477
S. 400, 405, 410.		
Light dolomite.	15	492
S. 415, 420, under microscope rounded brown grains.		
Dark dolomite.	40	527
S. 425, 430, oolitic; 435, 440, with pyrite; 445, 450, 455, dark, bituminous, possibly oolitic; 460 quite dark and rusty; 465 lighter, sharp pieces, oolitic signs?; 470, 475, 480. Note that Ford No. 23 is oolitic at 465-470.		
Light dolomite.	25	552
Stylolitic with black specks. Compare Ford No. 23, 505-510, 545, 550.		
S. 485, 490 are sugary but not oolitic, but the latter has grains of gypsum.		
Beginning of Salina?		
Impure gypsum.	45	597
Bluish, with some dolomite, and nearly pure at 525 feet.		
S. 495 stuck together; u. m. largely gypsum; 500 to 505 some gypsum; 510 bluish gypsum, with part limestone, briskly effervescing; 515 and 520 blue with white gypsum; 525 largely solid white gypsum; 530 brown and white gypsum and dolomite. Compare Ford No. 23, 590-640, Edison Ft. Wayne, 900-950, especially 925 with 525, this well running about 400 feet less (minus 62 ft. drift) than the Ft. Wayne; about 100 feet less than the Ford No. 23. Compare Church No. 5 at 720.		
S. 535, 540 oolitic with dark, oval bodies, 445, 450.		
Anhydrite is quite abundant at 565 + 62 ft. S. 555, darker, bluer, slow effervescence with gypsum; at 560 gypsum streaks; 565 mainly anhydrite. Compare Edison Ft. Wayne 1000 ft., Ford No. 23, 615-640. S. 570, 575 mixed; 580 cleaner buff dolomite; 585 u. m. mainly dolomite, bluish; 590, 595 mixed and bluish gray.		
Dolomite.	20	617
(Oolitic at 602 ft.)		
Bluish dolomite and anhydrite.	175	792
S. 600, 605, 610, 615, 620, 625, 630, 635, 640, 645, 650, 655, 660, all bluish, coarse chips, with occasional faint specks of anhydrite; 665, 670 similar, thinner brown calcinites; 670, 675, 680 similar; 685 u. m. almost wholly dolomite; 690, 695 and 700 the same; 705, 710, 715, lighter, with crusts of anhydrite and gypsum; 720 dolomite with no anhydrite; 725 stuck together, salty.		
At 730 ft. is the first salt. Compare 795 at Ford No. 23. The Edison Ft. Wayne well seems to have salt at higher levels, the first salt there at 1010 ft. belonging to the upper part of this group, apparently.		
Compare Church No. 5 at	890 ft.	
Eureka Wyandotte	730-800	
Ford No. 23	795	
Ford No. 22	819	
Ford No. 21	820	
Ford No. 7	792	
Ford No. 1	830	
Ford No. 4	783	
Solvay No. 11 and 12	865	
Solvay No. 13	880	
Solvay No. 14	875	
Solvay No. 15	865	
Solvay No. 16	890	
Romulus (Laurence and Griffeth)	925	
Tecumseh Salt Co.	828	
River Rouge Improvement Co.	815	
Brownies	875	
River Rouge Salt Co.	871	
Salotte & Ferguson	855	
Penn Salt Co.	830	
Detroit Salt Co.	906	
Stroh	1150	
Royal Oak	1543	
New Baltimore	1600	
St. Clair	1600	
Marine City	1604	
Port Huron	1500	

BRINE AND SALT DEPOSITS OF MICHIGAN.

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Salt.	50	842
S. 730 bluish, like rock above; 730-775 brown salt. This is the bed most likely to contain potash. S. 730, 735, 740, 745, 750, 755, 760, 765, 770, 775.		
Dolomite.	80	922
Hard. S. 780, 785, 790, 795, 800, slow effervescence, u. m. very little anhydrite, more just above the salt; S. 805, 810, 815, 820, blue and buff. Compare Ford No. 23, 922-927. S. 825, 830, 835, 840, 845, 850, 855, clear, buff, bluer at the bottom, very little anhydrite. Compare Wyandotte 870-900. Ford No. 23, 937-1000.		
Dolomite with anhydrite.	10	932
S. 860 u. m. much anhydrite; 865 anhydrite and dolomite.		
Anhydrite with salt.	10	942
S. 870, 875. While this is the second salt in this well, and would thus correspond to 940 ft. at Wyandotte Eureka, and 852 at Ford No. 23 (probably really to 1027) it is probable that these salt beds are not persistent. Edison Ft. Wayne 1280-1292 may also correspond. Ford No. 1 is the same.		
Dolomite.	5	947
This is merely a parting, but seems fairly persistent. Compare Ford No. 1, 968-976; Wyandotte 960.		
Salt.	15	962
S. 885 light gray, 890 white, 895 impure gray salt. Compare Ford No. 23, 1022-1046.		
Dolomite, anhydrite and clay.	100	1062
900 bluish and dark buff; 905 stuck together, salty, gray, and the rest of the samples to 995 are more or less stuck together; the effervescence moderate to slow; a little anhydrite generally visible under the microscope; the color, 910 gray and pink; 915 bluish and gray; 920 and 925 reddish and blue, salty; 930 not quite so red; 935 the same; 940 bluish, thin bedded, shaly; 945 the same; 950 quite muddy; 955, 960, 965 bluish; 970 blue, shaly; and 975, 980, 985, 990, 995, all similar, but the shaly stuff may have washed in from above. However, the coarser fragments are a bedded lime mud rock (dolomilitite). These correspond to the "slate" shaly beds in Ford No. 23, from 1046-1124. Compare also Wyandotte 970-1045; Church No. 6, 960-1160.		
Almost solid anhydrite.	5	1067
S. 1000 solid anhydrite, lighter in color and less shaly looking. Compare:		
Edison Ft. Wayne. 1400 ft.		
Wyandotte. 1045		
Ford No. 23.		
Dolomite and anhydrite.	50	1117
S. 1005 u. m. dolomite and anhydrite, buff; S. 1010 bluish, salty; 1015 like 995; 1020 buff; 1030 rather buff; 1035 a shade bluer; 1040 and 1045 some anhydrite is scattered in large grains in in dolomite. The base of this is the top of the main and it seems to me the most persistent salt bed.		
We should then compare:		
?Church No. 6, Trenton. 1280		
Wyandotte Eureka. 1080-1235 (less 45?)		
Morton. 1119-1323		
Romulus. 1475-1600 with partings.		
Milan. 1540-1545		
Zug Island. 1290-1528		
Solvay No. 11. 1370-1602 with parting.		
Edison Fort Wayne. 1445-1636		
Stroh. 1565-1815		
Royal Oak. 2115-2475		
Port Huron. 1991-2190		
Salt, dolomite and anhydrite mixed.	5	1122
Salt. Samples to 1075 + 62.	201	1323

Not including the brine salt, the production for Wayne county is shown in Table XXXIX.

TABLE XXXIX.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1895.	13,077	1901.	414,927	1907.	1,101,424
1896.	110,508	1902.	734,844	1908.	1,150,367
1897.	274,431	1903.	399,235	1909.	1,012,007
1898.	546,093	1904.	871,815	1910.	938,332
1899.	672,623	1905.	1,020,159		
1900.	370,912	1906.	1,168,629		

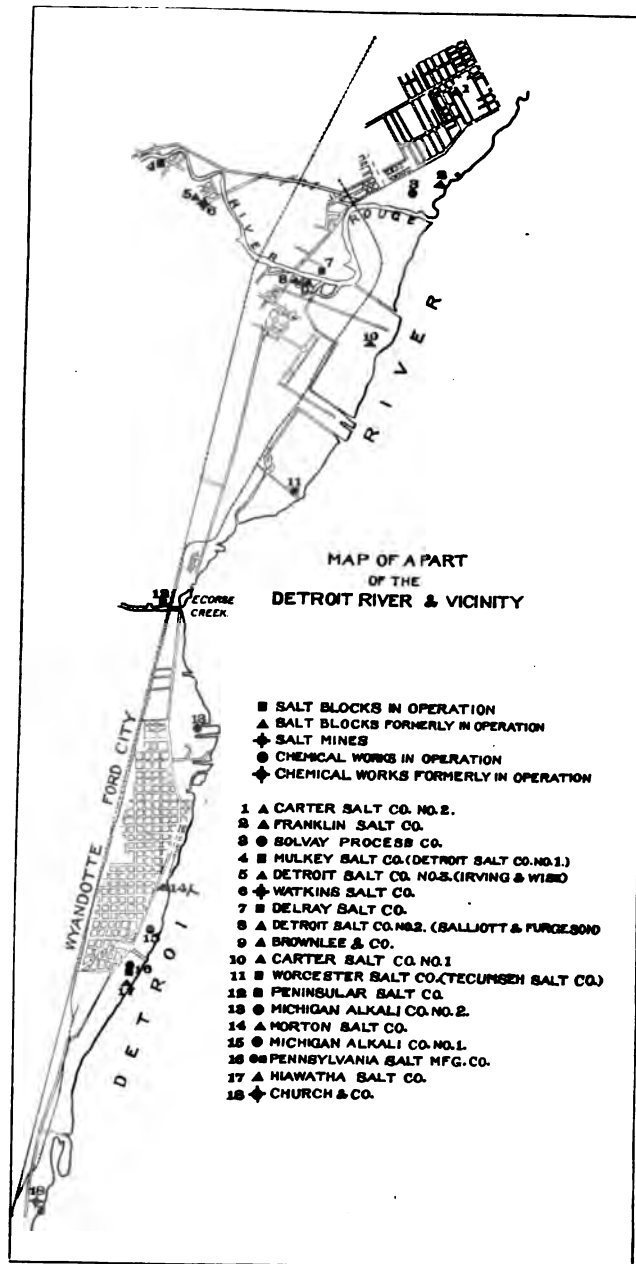
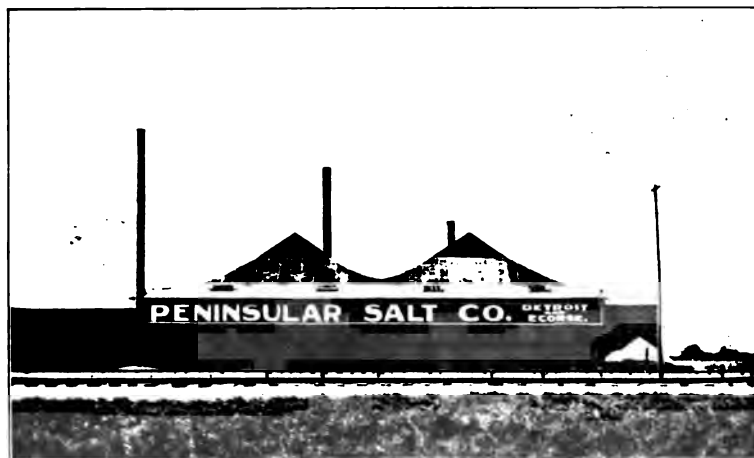


Figure 46. Map showing the location of salt blocks in Wayne county.



A. PENINSULAR SALT CO., ECORSE, MICHIGAN.



B. WORCESTER SALT CO., ECORSE, MICHIGAN.

Companies. (See Fig. 46).

Delray Salt Co. (Plate XIII B), Delray, Michigan. Incorporated, 1901. Capital stock, \$100,000.00. President, N. W. Clayton; treasurer, A. A. Nelson; general manager, Jos. P. Tracy.

The plant of this company which is located at the corner of Anspach and West Jefferson Ave., employs both the grainer and the vacuum pan processes. The grainer block contains six cement grainers (160'x16'), which are equipped with mechanical rakers. The brine, supplied by two wells, is stored in one cistern and preheated in one preheater before passing into the grainers. The vacuum pan block contains three pans, respectively 9, 10 and 11 feet in diameter, which are operated "triple effect." Live steam, supplied by three 335 horsepower boilers, is used in both the grainers and the vacuum pans. The daily capacity of the grainer block is 800 barrels of medium salt and that of the vacuum pan block, 1,200 barrels of granulated. The plant is also equipped to manufacture table salt, being therefore a producer of all grades of salt except rock salt. The storage capacity is 100,000 barrels and shipments are made both by rail and by boat.

Peninsular Salt Co. (Plate XIV A), Ecorse, Michigan. J. R. Bemmer, general superintendent.

The plant of this company, which is located at the south limits of Ecorse, at the junction of Ecorse creek and the Michigan Central tracks, was not in operation at the time of visitation and has not been operated since. It is equipped with two direct heat open pans (22'x100'), one cistern, which is piped and uses the exhaust steam from the pumps, and one well. The steam for the pumps is supplied by one 150(?) horsepower boiler.

Worcester Salt Co. (Plate XIV B), Ecorse, Michigan. Main offices, 168 Duane St., New York City. President and secretary, Lorenzo Burdick.

This company, which also has a plant at Silver Springs, N. Y., operates the plant formerly operated by the Tecumseh Salt Co. Both the grainer and vacuum pan processes are employed, the grainer block containing eight iron grainers (140'x12'x22") and the vacuum pan block, three ten-foot pans, two of which are run "double effect" and one, "single effect." Live steam is used in the evaporation and is supplied by six boilers, while the brine is furnished by two wells having a depth of approximately 1,525 feet. The daily capacity is 2,500 barrels and about forty per cent of the output is turned into table salt. Fifty men are employed in operating the plant.

Pennsylvania Salt Manufacturing Co., Wyandotte, Michigan. Offices, 115 Chestnut St., Philadelphia, Pa. Capital stock, \$10,000,.

000.00. President, Theo. Armstrong; vice president, Austin Purvis; secretary, J. T. Lee; treasurer, A. E. Rice.

Salt is manufactured by this company only as a by-product in the production of caustic and bleach, the exhaust steam from the chemical plant being used to evaporate the brine. The salt block contains one twenty-foot vacuum pan of the Ray type with a daily capacity of 200 tons. The product is disposed of to the Morton Salt Co.

Morton Salt Co. Offices, 717 Railway Exchange Bldg., Chicago, Ill. Plant, Wyandotte, Michigan.

The plant of this company, which has not been operated for several years, contains five wooden grainers provided with automatic rakers. Originally it also contained six V-grainers but preparations were being made to remove them at the time of visitation. The company possesses four wells the log of one of which has already been given. The steam for evaporation is supplied by twelve 150-horsepower boilers.

Detroit Salt Co., (Plate XV).

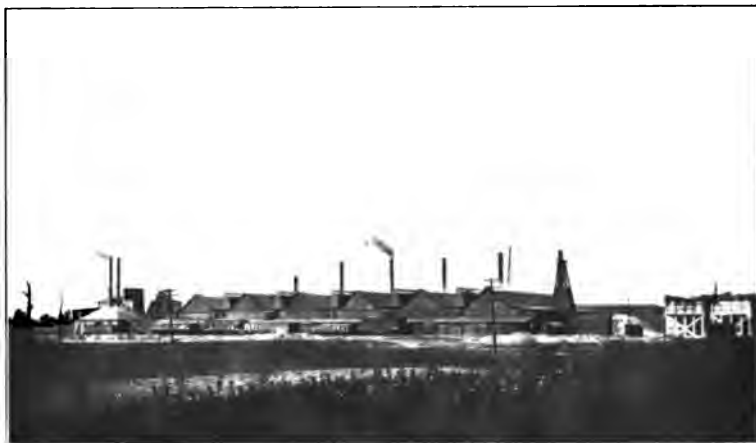
This company formerly operated two open pan blocks at Oakwood, grainer blocks at River Rouge and Wyandotte (Hiawatha Salt Co.), and the salt shaft at Oakwood. The larger of the two Oakwood blocks, known as Detroit Salt Co., No. 1, is now operated by the Mulkey Salt Co. The other block which was located at the salt shaft has not been operated for some years. The block at River Rouge burned in 1909 and the Hiawatha block was not in operation at the time of visitation. The mine as already indicated has been taken over by the International Salt Co.

The No. 1 block contains six open pans with no return flue, which have a daily capacity of 1,000 barrels. The brine, supplied by three wells, is stored in seven cisterns (16'x32'x6') and is not preheated before passing into the pans. About one-third of the output is turned into table salt. The storage capacity is 30,000 barrels and 125 men are employed.

Hiawatha block. This block contains three iron grainers (120'x14'x22") equipped with mechanical rakers. The brine is furnished by one well and is stored in a cistern (120'x10'x6') and preheated in a pre-heater of the same size. The plant also contains five boilers, the grainers having been operated on live steam.

Salt shaft. The description of the equipment is taken from the Engineering and Mining Journal,³¹ which also contains an account of the difficulties encountered in the sinking and the manner in which they were overcome. The equipment consists of a steel headframe 125 feet high in which is located a crushing plant similar to that employed for crushing coal. The hoist is of the Thompson-Greer type and is capable

³¹Fay, Albert H., Engineering and Mining Journal, Vol. 91, No. 11, 1911, pp. 565-569.



A. MULKEY SALT CO., OAKWOOD, MICHIGAN.



B. SHAFT OF WATKINS SALT CO., OAKWOOD, MICHIGAN.

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of operating to a depth of 1,500 feet at a speed of 1,800 feet per minute. The shaft is a three compartment one (6'x16') in the clear, and at the present time²² has a depth of 1,150 feet.

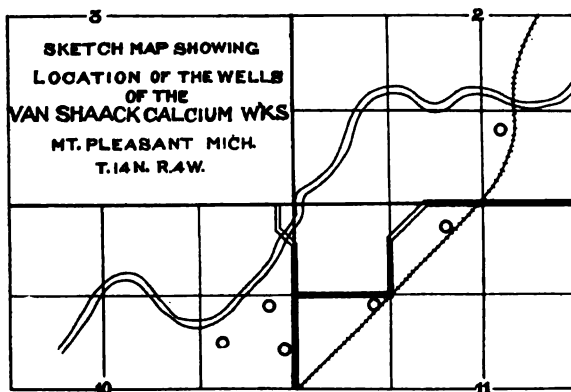


Figure 47. Sketch map showing the location of the wells of the VanSchaack Calcium Works.

ISABELLA COUNTY.

Since 1908, Peter Van Schaack and Son have manufactured a small amount of salt at Mt. Pleasant. As admission to the plant was denied, no description of the process or equipment can be given. The salt is manufactured as a by-product in the manufacture of calcium chloride and bromine, the former by Van Schaack and Son and the latter by the Dow Chemical Co. The brine employed is that of the Napoleon sandstone and at this point is much higher in the earthy chlorides than at Midland. The brine is obtained from six wells (see Fig. 47) with an average depth of 1,560 feet. The geological section at Mt. Pleasant is shown in the following well record.²³

Peter Van Schaak and Son, Mt. Pleasant. Elevation of the top of the well about 770 A. T.

Pleistocene.	
80	80 gravel, glacial outwash.
20	100 blue till.
20	120 quicksand.
160	280 blue till.
74	354 porous bed with water, coarse gravel on top, fine sand below.
26	380 red clay.
55	435 ground moraine till with broken coal measures.
Saginaw Coal Measures.	
185	620 black shale with streaks of coal (410', 435', 460') sandstone, limestone, or carbonate of iron and fire clay, mostly less than five feet thick.
90	710 fine white sandrock with mineral water.
80	790 gravelly sandrock with a strong flow of water, not so salt.
30	820 shale and red limestone.
Parma and Maxville.	
30	850 white limestone.
120	970 white sandstone with very salt water.
55	1025 white limestone fiercely effervescing.

²²January, 1913.

²³See Geol. Sur. Mich., Vol. IX, Part II, p. 90. Napoleon sandstone has been inserted, otherwise the record is unchanged,

Lower Grand Rapids or Michigan Series.

5	1030 shale.
20	1050 sandstone.
75	1125 dolomite and shale.
100	1225 anhydrite and dolomite.
45	1270 anhydrite nearly pure (gypsum).
103	1373 dolomite, shale and anhydrite.
8	1381 sandstone.
5	1386 shale.
4	1390 sandstone.
15	1405 shale.
Napoleon Sandstone.	
160	1565 sandstone, dark with heavy brine.

The production which has been exceedingly small is given in Table XL.

TABLE XL.

Year.	Barrels.	Year.	Barrels.	Year.	Barrels.
1908.....	8,312	1909.....	9,373	1910.....	4,954

APPENDIX A.

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APPENDIX B.

AN ACT TO REGULATE THE MANUFACTURE, AND PROVIDE FOR THE INSPECTION OF SALT.

(323)¹ Sec. 1. The people of the State of Michigan enact, That no salt manufactured or mined in this State, after this act takes effect, shall be sold within or exported from this State until the same shall be duly inspected, as provided in this act. Any persons who shall violate the provisions of this section shall pay, for the use of the people of this State, as a fine, the sum of one dollar for each barrel or portion thereof of salt sold or exported contrary to the provisions of this act. In case any manufacturer or producer of salt shall, knowingly, sell or export, or permit to be sold or exported, salt, contrary to the provisions of this act, he shall, upon conviction thereof, be liable to a fine not exceeding one thousand dollars or imprisonment in the county jail not exceeding ninety days: *Provided*, That nothing in this act shall apply to salt packed or purchased and in the hands of producers or dealers when this act takes effect.

(4912)² Sec. 2. Immediately after the expiration of the present inspector's term of office, and every two years thereafter, there shall be appointed by the governor of this state, and by and with the advice and consent of the senate, an inspector of salt, who shall be a person of competent skill and ability, and who shall hold his office for two years and until his successor shall be appointed and qualified, unless sooner removed for cause. He shall at all times be subject to the removal of the governor for cause; and in addition to other causes which may arise, incompetency and inefficiency in the performance of the duties devolved upon him by this act, shall be deemed good cause for removal. In case of vacancy in the office, it shall be the duty of the governor to fill the same by appointment, immediately upon receiving notice thereof, and such appointment shall hold until the close of the next session of the senate; and, in the meantime, the governor shall, with the consent of the senate, appoint to fill the vacancy for the unexpired portion of the term.

(4913) Sec. 3. Immediately after his appointment and qualification, the inspector shall divide the salt-making territory of this state into so many inspection districts as he may judge necessary, and shall

¹ (323), etc., Public Acts of 1905.

² (4912), etc., Compiled Laws of 1897.

appoint for each district one or more competent and efficient deputy inspectors, who shall hold office at the pleasure of the inspector, and for whose acts he shall be responsible. Such districts may be changed from time to time, as may be necessary. The inspector shall give his entire time, skill and attention to the duties of his office, and shall not be engaged in any other business or occupation.

(323) Sec. 4. The inspector shall be entitled to receive an annual salary of fifteen hundred dollars; he shall also be allowed the further sum of three hundred dollars, annually, for the expenses of providing and furnishing his office and for clerk hire, stationary, books and printing; and such further sum as he may actually and necessarily expend in traveling, and other expenses, in an amount not to exceed seven hundred dollars per annum, which shall be incurred in the proper discharge of his duties; his deputy shall be entitled to such sums in each case as he may approve, not exceeding, in any case, the sum of one hundred dollars per month for the time actually employed: *Provided*, That such deputy inspectors may be allowed their necessary expenses in addition to the above sum when employed outside their respective districts. All salaries and expenses provided for by this act shall be retained by the inspector out of the money received, under the provisions of section five of this act, and accounted for and paid out by him, as provided by this act, which salaries shall be paid monthly: *Provided*, That in case the money received for the inspection of salt, according to the provisions of section five of this act, shall not be sufficient to pay the salaries and expenses of the inspector and his deputies, as provided for herein, that the amount of such deficiency shall be deducted from said salaries, pro rata to each.

(323) Sec. 5. Each person, firm, company, and corporation engaged in the manufacture or production of salt, or for whom any salt shall be inspected, shall, from time to time, as salt is inspected, or offered for inspection, pay on demand, to the salt inspector or the deputy of the district where the salt is inspected, three mills for each two hundred eighty pounds of salt inspected or offered for inspection: *Provided*, That the same may be required by the inspector to be paid in advance: *And provided further*, That but one inspection fee shall be paid upon the same salt. In case any person, firm, company, or corporation shall neglect or refuse to pay such inspection fees on demand at his, their, or its office, manufactory, or mine, the party so refusing, shall be liable in an action therefor, in the name of the inspector, and the certificate of inspection, with the proof of the signature of the inspector or deputy inspector, giving the same, shall be prima facie proof of the liability and the extent of the liability of the party so in default; and it shall be lawful for the inspector and his deputy to refuse to in-

spect salt manufactured at the works, manufactory, or mine so in default, until the amount due is paid. All money received by or paid to any deputy inspector, under this section, shall be forthwith paid to the inspector. The inspector shall keep just and true accounts of all money received under this section, and an account of the amounts received from or paid by each person, firm, company, and corporation engaged in the production of salt, and all other things appertaining to the duties of the office, and the said books and accounts shall always, during office hours, be subject to the inspection and examination of any person who may wish to examine them, and shall be handed over to his successor in office, together with all the money and effects appertaining to said office.

(4916) Sec. 6. The inspector shall, before entering upon the duties of his office, take the oath prescribed by the constitution of this state, which oath shall be filed in the office of the secretary of state. He shall execute a bond to the people of this state in the penal sum of seven thousand dollars, conditioned for the faithful performance of the duties of his office, which bond shall have at least two sureties, and shall be subject to the approval of the state treasurer; and when approved shall be by such treasurer filed and deposited in his office; and the inspector shall renew his bond each year. Any person or corporation injured by the neglect or default of such inspector, or by his misfeasance in office, or by the neglect, default or malfeasance (misfeasance) of any of his deputies, may maintain an action on such bond in the name of the people, for the use of the party prosecuting, and shall be entitled to recover the full amount of damages sustained.

(4916) Sec. 7. Each of the deputies appointed by the inspector shall take the oath of office prescribed by the constitution, and shall give bond to the inspector in such sum, and in such sureties as he may approve, conditioned for the faithful performance of his duties as such deputy; and in case said inspector shall be obliged to pay any sum for the neglect or default, or misfeasance of any deputy, he may recover of such deputy, and his sureties on such bond, the amount he was obliged to pay, with accruing costs.

(323) Sec. 8. The inspector shall keep a principal office in some one of the principal salt producing districts of this State, and the deputy inspector for the district, in which such office is located may occupy the same office. Such office shall be open at all times during business hours. All the books, records and accounts shall be kept in such office, and each deputy inspector shall, at least once a month, make a written report, by mail or otherwise, to the inspector, of salt inspected by him, during the month, stating for whom, and the quality and quantity thereof. Abstracts of these reports shall be entered in books for

that purpose. Said inspector shall, in proper books, keep a complete record and account of all his transactions, and such books shall also be open for the examination of all persons wishing to examine the same during office hours.

(4919) Sec. 9. The inspector shall not be concerned in any way in the manufacture or selling of salt, or have any interest, directly or indirectly, in any salt manufactory, or erection for manufacturing salt in the state of Michigan, or in the profits of any such manufactory.

(4920) Sec. 10. It shall be the duty of the deputy, in each district, to visit once in each day, Sundays excepted, each salt manufactory in his district, when in operation, and to ascertain if there be therein any salt of bad quality, and such as ought not to pass inspection.

(4921) Sec. 11. It shall be the duty of the inspector to visit the manufactories in which salt is made, that may be in operation in the different districts, as often as practicable.

(4922) Sec. 12. The inspector or deputy, at each visit, as provided in this act, shall carefully examine the salt in the bins, and the brine in the kettles, or pans, or vats in which the salt is manufactured; if the salt in the bins, or any part thereof is of bad quality, and such as ought not to pass inspection, or if the brine in the kettles, or pans, or graining vats have not been cleansed, he will direct and see that the owner, or occupant, or boiler, or other person having charge of the manufactory, remove the bad salt from the bin, and place it with the second quality salt, or throw it among the bitters, as the inspector or deputy may direct, and the impure brine in the kettles, or pans, or graining vats be thrown out, and new brine substituted.

(4923) Sec. 13. No lime or lime water shall be used by any person in the manufacture of salt, in the kettles, or pans, or graining-vats used for manufacturing, under a penalty of twenty-five dollars and costs for each offense, to be sued for in the name of the people of this state; *Provided*, That iron vessels used in the manufacture of salt may be whitewashed, when cool, to prevent the accumulation of iron rust.

(4924) Sec. 14. Every person desiring to have salt inspected, shall apply to the inspector or deputy inspector of the district where the same shall be, which inspector or deputy inspector shall thereupon actually examine the salt so offered for inspection, in the package in which the same may then be.

(4925) Sec. 15. To facilitate such examination, it shall be the duty of the person or company offering the salt for inspection, to unhead or bore the barrel, or to open the bag or other package in which the salt is contained, as may be directed by the inspector or the deputy inspector, so as to expose the salt to his touch, view and examination.

(4926) Sec. 16. The inspector, or deputy inspector, shall not pass

any salt as good, unless he shall find it well made, free from dirt, filth and stones, and from admixture of lime, or ashes of wood, and of any other substance which is injurious to salt, fully drained from pickle, the bitters properly extracted therefrom, and manufactured as directed by this act, and the rules and regulations of the inspector.

(4927) Sec. 17. The company or persons offering the same for inspection, shall in all cases provide the necessary force to lift the salt while the deputy or inspector measures it, and shall also furnish the necessary help and material to brand the salt for and under the direction of the inspector or deputy inspector.

(4928) Sec. 18. Each manufacturer shall provide a scale or balance at his works, to be examined from time to time, and approved by the inspector, in which all the salt offered for inspection at his works may be weighed.

(4929) Sec. 19. Each inspector or deputy shall deliver to the party for whom he shall inspect the salt, a certificate of the quality and quantity inspected, and shall thereupon direct the employees of the manufacturer to brand and mark, under his personal supervision, with durable paint, the package containing the salt so inspected, with the surname of the inspector at length, and the initials of his christian name, with the addition of the word "inspector" in letters at least one inch in length, and shall also be caused to be marked or branded by the employees of the manufacturer upon the head of the barrel, cask, or package, the weight prescribed for such barrel, cask, or package by the inspector, when such weights are in conformity to the rules and regulations prescribed by the inspector in that regard; and if such weights do not correspond to the rules and regulations he shall cause the same to be repacked so as to conform thereto.

(4930) Sec. 20. If the said salt shall be put up in barrels it shall not be marked unless the barrels are thoroughly seasoned, stout, and well made, with such number of hoops as shall be prescribed by the inspector, to be well nailed and secured.

(4931) Sec. 21. Every person who shall falsely or fraudulently make or counterfeit, or cause to be made or counterfeited, or knowingly aid or assist the false or fraudulent making or counterfeiting the mark or brand of any inspector or deputy inspector, on any package containing salt, shall be deemed guilty of felony, and on conviction thereof, shall be subject to a fine of not less than one hundred nor more than one thousand dollars, or be imprisoned in the state prison for a term not less than one and not more than six years, or both in the discretion of the court.

(4932) Sec. 22. No manufacturer or other person shall pack, or cause to be packed, or sell, or offer for sale in barrels, casks, boxes,

sacks, or in bulk, any salt, until the inspector shall have determined, upon actual examination, that the same is sufficiently drained of pickle, and otherwise fit to pack. All salt shall stand in the boxes at least twenty days before packing, and the time will be taken to commence from the last discharge of wet salt into the bins; nor will the packing of any such salt be allowed until the same has been declared fit for that purpose upon actual examination by the inspector or his deputy, and the packing of any salt without express permission, although twenty days may have elapsed, shall not be allowed.

(4933) Sec. 23. The inspector and his deputies, in their daily examination of the several salt manufactories, shall examine all bins of salt for the purpose of ascertaining whether any salt is packed contrary to the provisions of the foregoing section.

(4934) Sec. 24. If any manufacturer or other person shall pack any salt before the inspector or one of his deputies shall have determined that it is fit for packing, he shall forfeit the sum of twenty-five cents for every bushel of salt so packed.

(4935) Sec. 25. Barrels, casks or sacks in which salt shall have been packed and inspected, shall not be used again for the packing of salt therein, until the marks or brands made by the inspector shall first be cut out or removed; and if any person shall pack, or cause to be packed, or shall aid or assist in packing any uninspected salt in any such barrels, casks, or sacks, without first cutting out or removing such marks or brands, he shall forfeit, for every bushel of salt so packed, the sum of one dollar.

(4936) Sec. 26. It shall be the duty of every manufacturer to brand or mark, with durable paint, every cask or barrel of salt manufactured by him, with the surname at full length of the proprietor or owner of the manufactory at which the same shall have been made, and the initial letters of his christian name, and if the same shall have been manufactured for a company, or association of individuals, he shall mark or brand, in a like manner, upon every such cask or barrel, the name by which the company is usually called: *Provided*, That no second quality salt shall be so marked.

(4937) Sec. 27. No inspector or deputy inspector shall inspect or pass any barrel, cask, box, or sack of salt which shall not be marked or branded in the manner prescribed in the last section, and the inspector or deputy shall not affix his brand to any barrel which shall not have been so branded by the manufacturer offering the same for inspection: *Provided*, That none of the provisions of this section shall apply to second quality salt: *And provided further*, That the inspector may, by regulations prescribed by him, provide that both the brand of the manufacturer and that of the inspector shall be put upon each package at the same time.

(4938) Sec. 28. Salt of an inferior quality—dirty, damaged or condemned—may be sold loose, or in bulk, by the manufacturer thereof, at the works, the inspector making bills of the same, designating the quantity by weight, as in ordinary cases, and distinguishing the same as "second quality;" or such inferior salt may be packed in boxes, barrels, casks or sacks, and branded by the inspector with the words "second quality salt," in plain letters not less than one inch in length, and such inspector shall add the initials of his name, and no other or different brand shall be placed thereon; and said second quality salt, subject to the provisions of this section, may be sold or exported by the owners as such.

(4939) Sec. 29. Every person who shall forge or counterfeit the name so required to be put on by the manufacturer, or shall cause, or procure to be put on any barrel or cask in which salt shall be packed, the name of any person other than that which should properly be placed thereon according to the provisions of this act, shall, for every such barrel, cask, or sack, forfeit the sum of one hundred dollars, and shall be liable for all damages to the party aggrieved.

(4940) Sec. 30. The inspector shall, by regulation from time to time, specify the quantity of salt that shall be contained in bags or other packages which shall be offered for inspection. And it shall not be lawful for him to authorize the inspector's brand to be placed upon any package that does not correspond with said regulation.

(4941) Sec. 31. The inspector shall by regulation, require that all ground salt manufactured and put upon the market, shall be legibly marked upon each keg, box, sack, bag, or other package containing the same, with the words "ground solar," "ground boiled," or "ground steam," or "ground Chapin," as the fact may be. Such marking to be done by letters not less than one inch in length.

(4942) Sec. 32. If the inspector shall consent to, connive at, aid or abet, the smuggling of salt, or the transportation of the same away, so as to invade the inspection thereof, or shall accept of any bribe, or sum of money, or any gift, or reward whatsoever, upon any expressed, or secret or implied trust, or confidence that he shall connive at, or consent to any evasion of the laws for the inspection of salt, such inspector shall forfeit his office, and pay to the use of the people of this state the sum of one thousand dollars.

(4943) Sec. 33. If any deputy inspector shall be guilty of the offenses specified in the last section, or any of them the inspector appointing such deputy shall forfeit to the use of the people of this state the sum of two hundred and fifty dollars, for the recovery of which his bond shall be put in suit.

(4944) Sec. 34. The inspector and each of his deputies shall be

exempt from serving on juries, and from all military service, except in the case of actual invasion or insurrection; and the commission or appointment in writing of any such officer or deputy shall be evidence of the facts stated therein.

(4945) Sec. 35. The inspector shall have the power from time to time, to make and ordain such necessary rules and regulations as he may deem expedient, concerning:

First, the manufacturing and inspecting of salt not inconsistent with the provisions of this act;

Second, the daily examination, and reporting by his deputies, of the operation and extent of the several salt manufactories, so as to determine whether the quantity inspected at each manufactory, is equal to the quantity actually manufactured thereat;

Third, the districting of the salt-making territory in this state, and the duties of his deputies under this act, and he may alter and revoke such rules and regulations at his pleasure.

(4946) Sec. 36. The inspector shall have the power to annex penalties, not exceeding ten dollars in any case, to the violation of such rules and regulations; such rules and regulations shall be printed and posted up in the office of the inspector, and in each manufactory, and published at least once in some newspaper in each county where salt is manufactured, and shall, after they have been posted and published as aforesaid for one week, be binding upon all persons concerned.

(4947) Sec. 37. It shall be the duty of the inspector and his deputies, upon being applied to by any manufacturer to inspect salt in his district, to inspect the same forthwith; and in no case shall the inspector, or any deputy, delay the inspection beyond twelve hours of daylight, excluding Sundays, after such application unless such manufacturer shall consent to the delay. For the violation of this section by the inspector, or any one of his deputies, the inspector and his sureties shall be liable to the party aggrieved in the sum of fifty dollars over and beyond actual damages sustained.

(4948) Sec. 38. Nothing in this act shall be construed so as to prevent the sale or exportation of the bitterns from any manufactory of salt, such bitterns to be sold or exported in bulk, or if in casks or barrels, to be branded as bitterns, and sold or exported as such.

(4949) Sec. 39. In case of any vacancy from any cause, in the office of the inspector, the deputy who has been longest continuously in office shall possess the powers and perform the duties of the inspector until such vacancy shall be filled; and the bond of the inspector and his sureties shall continue to be liable for the acts of all the deputies until such vacancy shall be filled.

(4950) Sec. 40. The inspector shall annually, in the month of

December, and on or before the fifteenth day thereof, make a report to the governor of this state, which shall contain:

First, the number of districts into which the salt-producing territory of the state may then be divided, with the name and locality of each, and the number and capacity of the works of each district;

Second, the quantity and quality of salt inspected in each district during the preceding year;

Third, the amount received, and the expenses incurred under this act for the preceding year, in detail;

Fourth, such suggestions and recommendations as he may think proper to make concerning the manufacture of salt, and the operation of the inspection laws upon the same, and as to what further legislation upon the subject, if any, would be advisable. A copy of such report shall be published immediately after its date, in some paper in the Saginaw valley.

(4951) Sec. 41. The inspector shall establish a grade of "fine" salt, the grain of which shall be at least as fine as the average grain of salt made in kettles. He shall cause the word "fine" to be marked on packages containing such salt, in large letters, and the word "fine" without any qualification, shall not, under any circumstances, be placed on salt of coarse grain; but all other grades shall be designated on the packages by some truly descriptive mark or brand, and the inspector may mark salt "second quality" for imperfect grain, as well as other defect.

(4952) Sec. 42. Nothing in this act contained shall be construed to prevent the sale or shipment of salt in bulk, after the same shall have been duly inspected, and a certificate thereof given by said inspector, or any deputy; and nothing in this act shall be construed to prevent manufacturers from putting such private trade-mark or brand on their salt as they may see fit: *Provided*, It contains no untruth, or statement calculated or intended to deceive the purchaser.

(4953) Sec. 43. In case the inspector shall, at the time of making any annual report, have a surplus of money arising from the inspection fees in this act provided for, in his hands, he shall apportion back and pay such surplus to the persons, firms or corporations for whom salt has been inspected during the last preceding year in proportion to the amounts paid by them respectively for inspection fees: *Provided*, That in no case shall the state be held liable for any obligation or expenditure in consequence of any of the provisions of this act.

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